DOCUMENT RESUME

ED 116 373 EC 080 695

AUTHOR	Walton, Wendel K.
TITLE	A Tympanometry - ASHA Model for Identification of the Hearing Impaired. Project TAMI.
INSTITUTION	Capitol Region Education Council, Windsor, Conn.
SPONS AGENCY	Connecticut State Dept. of Education, Hartford. Bureau of Pupil Personnel and Special Education Services.
PUB DATE	May 75
NOTE	155p.
EDRS PRICE	MF-$0.76 HC-$8.24 Plus Postage
DESCRIPTORS	Audiology; Audiometric Tests; *Auditory Tests; *Aurally Handicapped; Elementary Education; Exceptional Child Research; Guidelines; *Identification; *Models; *Screening Tests
IDENTIFIERS	Project TAMI; *Tympanometry

ABSTRACT

A model for identification of hearing impairment which combined tympanometry and the puretone procedures outlined by the American Speech and Hearing Association was tested with 8,528 elementary age children from six Connecticut towns. The nine goals of the project included obtaining pass/fail ratios for puretone audiometry within minus 1 percent and plus 3 percent of national prevalence statistics, obtaining a normative data base for a combined puretone-tympanometry model representative of the various populations within Connecticut, and determining the reduction of false positives resulting from a rescreening of all initial screen failures. All goals were met except the goal of having the model adopted in at least two of the participating towns. It was concluded that routine inclusion of tympanometry in hearing conservation programs for schools is both practicable and desirable, and that nursing and hearing personnel can be taught quickly to operate the equipment and obtain reliable data. (Appendixes to the document include statistical findings from the screening, guidelines for puretone testing and tympanometry, and various forms for recording information and for referral.) (LS)

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ED116373

PROJECT TAMI

A Tympanometry-ASHA Model for Identification of the Hearing Impaired

Wendel K. Walton, Ph.D.

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This investigation was made possible by a grant from the
Connecticut State Department of Education,
Bureau of Pupil Personnel and Special Educational Services,
under Title VI, Part B, of Public Law 91-230

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May, 1975

EC 080 695

ACKNOWLEDGEMENTS

Prominent among those who made significant contributions to this investigation were the following: Mary Anne Libby, Assistant Director; Louise Goldberg and Joan Panciera, project audiologists; Carma Walton who organized and directed the efforts of the volunteers; Don Berg who was responsible for the photography and graphic artwork and also prepared the manuscript for printing; Danny O'Neill and Tom Metzner who wrote the computer programs; and Claire Messier who typed and Suzanne Johnson who edited the manuscript.

Additionally, recognition is due Dr. John Allison, Executive Director of the Capitol Region Education Council and his administrative staff; the Nursing and the Speech and Hearing Supervisors in the participating towns and their respective staffs; the 352 parent volunteers who carried out the myriad assortment of support tasks; and Dr. Tom Gillung, Director of the Special Education Resource Center.

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IDENTIFICATION AUDIOMETRY IN CONNECTICUT

The purpose of identification audiometry in the schools is to detect those children who may be educationally handicapped by hearing loss. It is the cornerstone upon which the hearing conservation program of a school district is built. As stated by the National Conference on Identification Audiometry (Darley, 1961),

> . . . the goal is to locate children who have even minimal hearing problems so that they can be referred for medical treatment of any active ear conditions discovered to be present and so that remedial educational procedures can be instituted at the earliest possible date. Programs should be designed to identify not only children with a chronic disability but also children who have difficulty during only certain times of the year or under certain conditions. The period when a child may not be hearing well (as during a respiratory illness or during a season with high pollen-count) and consequently be functioning at a low level may be just the time when social and educational demands on him are great.

Identification audiometry involves a considerable expenditure of professional time and equipment resources by school districts. The few existing studies on the accuracy of identification audiometry (Melnick, et al., 1964; Wilson and Walton, 1974), have shown that through careful attention to equipment calibration, monitoring of ambient noise levels in the testing environment, and the training and preparation of all testing and support personnel, the hearing status of elementary school children may be correctly categorized 95 percent of the time.

NATIONAL PREVALENCE OF HEARING IMPAIRMENT

In an identification audiometry study of 7800 school-age children in the Renton, Washington, School District, Walton and Wilson (1972) found the following percent failures on initial screening: kindergarten-14.8 percent, first grade-13.2 percent, second grade-14.2 percent, third grade-9.7 percent, fifth grade-9.5 percent, eighth grade-11.4 percent, eleventh grade-13.5 percent. Melnick, et al., (1964) reported that 20.4 percent of 860 school-age children failed an initial puretone screening. It is noteworthy that the children tested by the latter authors were familiar with the testing procedures and were examined in specially prepared, sound-isolated environments.

In 1972, Gallaudet College published the results of a national survey of state identification audiometry programs and special educational services for hearing impaired children and youth in the United States (Gentile, 1972). Twenty-three states reported sufficient data to permit the following extrapolations:

(1) The median percent failing puretone screening equaled 7.6, with a range of 4.6 to 29.6 percent.

(2) The median percent failing puretone threshold testing was 4.1, with a range of 2.8 to 6.1 percent.

(3) The median percent referred for medical management was 2.6, with a range of 1.4 to 8.2 percent.

CONNECTICUT PREVALENCE

Data on Connecticut's identification audiometry programs were

unavailable at the time of the Gallaudet study. Subsequently, a survey of the health services provided in Connecticut Schools during the 1972-1973 school year was conducted by the Departments of Health and Education. Reports on auditory screening were received from fifty-six towns, representing 111,844 school-age children.

Contrasting with the median values reported for the nation, the percent failing puretone screening in Connecticut ranged from 1 percent to 30 percent with a median of 4.7 percent. The percent failing threshold testing was 2.2, and the median percent referred to physicians was 1.5. Reportedly, testing was conducted at the following frequencies and hearing levels (ISO): 250 Hertz (Hz), 25 dB; 500 Hz, 25 dB; 1000 Hz, 20 dB; 2000 Hz, 20 dB; 4000 Hz, 30 dB. Available space was utilized with no provision for sound isolation.

Considering the frequencies and hearing levels employed and the lack of sound isolated test environments, it is remarkable that so few failed. The single report of 30 percent failure is also of concern. Too low a percent failure suggests a high false-negative category (and under referral for medical and educational attention), whereas the report of 30 percent failure suggests a high false-positive category (and over referral). Both are causes for concern as to the validity of the identification audiometry being conducted. As expressed by many of the nurses and the speech and hearing clinicians involved in the testing, the identification programs suffer for want of proven models.

Local attitudes in Connecticut differ as to whether an identification

audiometry program should focus on the detection of those children needing medical attention or on those needing educational attention. Because of the prevalence of middle-ear pathologies among children in the primary grades and the frequency with which such conditions eventually affect puretone sensitivity, ideally a model program should include provision for both. Having previously examined the accuracy of the American Speech and Hearing Association's (ASHA) guidelines for auditory screening programs in schools (Chaiklin, et al., 1975; Wilson and Walton, 1974), and considering the works of Randolph (1974), Renvall, et al. (1973), and Brooks (1968, 1969, 1971a, 1971b, 1973, 1974) on the use of tympanometry with school children, it was concluded that joining tympanometry with the puretone procedures outlined in the ASHA guidelines would provide the basis for a comprehensive, viable model.

DEFINING THE PROBLEM

Because of questionable reliability and validity, current identification audiometry programs in Connecticut are suspect. Based on national prevalence data, it is probable that many primary age children with potentially educationally handicapping hearing impairments are not being identified in order that appropriate educational and medical attention may be obtained. Subordinate to this major problem, nine specific problems were defined and addressed:

SUBORDINATE PROBLEM - 1

Lacking a specific mandate for, and specification regarding puretone identification audiometry in schools, current procedures employed in Connecticut lack coordination and discipline, resulting in a serious under-identification of children with potentially educationally handicapping hearing impairments.

Background

Identification audiometry is conducted in Connecticut schools under Section 10-205 of the General Statutes which mandates broadly that every child receive a physical examination at least once in each three-year interval.

Puretone identification audiometry procedures adapted to the needs and facilities typical of the public schools were developed by the American Speech and Hearing Association (Chaiklin, et al., 1975) and the accuracy of these procedures were established by Wilson and Walton (1974).

Procedures

The procedures developed by ASHA for conducting puretone identification audiometry programs in schools were applied in a feasibility study of their applicability to Connecticut.

Measures

Pass/fail ratios per grade level were compared to like data reported elsewhere (Wilson and Walton, 1974; Gentile, 1972; Melnick, et al., 1964).

Goal

The goal was to obtain pass/fail ratios within minus 1 percent and plus 3 percent of national prevalence statistics.

SUBORDINATE PROBLEM - 2

Puretone air conduction audiometric procedures generally are ineffective in detecting mild, conducive hearing impairments.

Background

Children with "sub-clinical" losses in hearing sensitivity resulting from abnormal middle ear conditions may be undetected by conventional audiometric testing techniques (Eagles, 1972). Use of bone conduction audiometry is precluded by a lack of skilled personnel and sound isolated test environments.

Procedures

Tympanometry was employed as an objective technique for ascertaining middle ear status.

Measures

Middle ear pressure and compliance values obtained during a mass hearing screening program were compared to relevant data in the literature.

Goal

The goal was to determine the pressure and compliance values suitable for recommendation as pass/fail criteria for children included in mass screening programs employing tympanometry.

SUBORDINATE PROBLEM - 3

Personnel responsible for testing lack formal training and guidance in appropriate procedures and frequently utilize aides and volunteers in the actual execution of the puretone audiometry.

Background

State regulations and/or guidelines specifying the qualifications necessary to conduct identification audiometry programs in schools do not exist. Personnel involved in the screening procedures need instruction and guidance in the operation of equipment, the factors affecting reliability and validity of test results, and direct supervision in perfection of technique.

Procedures

All testing personnel included in the project received from eight to 12 hours of direct instruction in audiometric and tympanometry testing procedures. In addition, project audiologists provided

"on-line" supervision and guidance during the course of the testing phase in order to assure that uniform test protocols were followed.

Measures

Measures of the effects of training were (1) observation of performance during the training and testing phases, (2) the number of personnel adopting the procedures presented, (3) the number of personnel completing the training phase and (4) the acceptance of the procedures as reported in an opinion survey.

Goal

The goal was adoption of the recommended procedures by a minimum of 50 percent of those completing training.

SUBORDINATE PROBLEM - 4

Educationally and medically significant hearing impairments in school-age children are not being identified; thus, comprehensive educational and medical attention is not received.

Background

A composite model including puretone audiometric and tympanometric techniques has not been field tested to determine the practicability of such for general utilization.

Procedures

A composite model for identification of hearing impaired children in elementary schools, utilizing both puretone audiometric and tympanometric procedures was field tested in selected communities in Connecticut.

Measures

Measures of the practicability of the combined model included (1) use of a questionnaire to determine professional acceptance of the model, (2) measures of the time required per child for both types of testing, and (3) measures of the total number of children tested per time period allocated to each participating town.

Goal

The goal was to determine the practicability of the model and to have it adopted by at least two of the six communities which participated in the study.

SUBORDINATE PROBLEM - 5

Excessively time consuming audiometric screening programs disrupt class and school routines, impairing public and professional acceptance.

Background

Rapid and accurate identification procedures are needed in order that attention may be obtained quickly and supportive attitudes developed.

Procedures

To reduce the testing time required, aides and volunteers were used for traffic management, data recording, and as integral members of coordinated testing teams. The teams were composed of aides and volunteers, nurses and speech and hearing personnel (who performed the actual testing), and at least one member of the TAMI supervisory staff.

Measures

Efficiency was determined by the time required per child for both tympanometry and puretone screening, as well as the total number of children tested per day, per school. Measures of accuracy were the agreement between pass/fail ratios obtained in this study and the data in the literature for similar testing procedures.

Goal

Given that all Kindergarten, first, second, third and fifth-grade pupils were to be tested from a minimum of five schools per participating town, the goal was to test an average of one child per minute utilizing three teams simultaneously.

SUBORDINATE PROBLEM - 6

Normative data do not exist for the pass/fail ratios or the pressure and compliance values to be expected from a combined puretone-tympanometry screening model.

Background

A broad, normative data base for a combined puretone-tympanometry model is needed in order that statistically justifiable and practicable criteria may be established for differing elementary grades, sex, socio-economic levels, and ethnic/racial comparisons.

Procedures

The necessary data base was provided by six Connecticut communities with at least five elementary schools per community.

Measures

The percent ethnic distribution, the choice of schools and towns, and the total number of elementary school children per grade were measures employed to determine the composition of the data base.

Goal

The goal was to obtain a data base representative of the various populations within Connecticut.

SUBORDINATE PROBLEM - 7

Melnick, et al (1964) and Wilson and Walton (1974) independently have stated that approximately 50 percent of those failing an initial puretone screening will pass when re-screened within a seven-day period. Such data do not exist for a combined puretone-tympanometry model.

Background

In order to reduce the percent of over referrals, it is necessary that the screen-rescreen pass/fail ratios for a combined puretone-tympanometry model be determined.

Procedures

Children failing either a puretone screening or a tympanometric screening received a re-screening within seven calendar days.

Measures

The screen-rescreen pass/fail ratios for puretone screening and tympanometry were determined.

Goal

The goal was to determine the reduction of false positives resulting from a rescreening of all initial screen failures.

SUBORDINATE PROBLEM - 8

Conductive hearing problems are seasonally related, yet auditory screening programs are often conducted throughout the school year.

Background

Because of difficulties associated with the scheduling of personnel, space, and equipment, it is usually considered infeasible to compress auditory screening into a limited number of days or weeks during the school year; yet seasonal effects upon the results are unknown.

Procedures

Approximately one-half of the total number of students were tested during the late winter months and one-half were tested during the spring months.

Measures

Pass/fail ratios per test were compared for the winter and spring months.

Goal

The goal was to determine the relative effects of these seasons on puretone and tympanometric screening conducted during the winter and spring months.

SUBORDINATE PROBLEM - 9

Inordinate time lapses between the identification of a problem and the initiation of educational and/or medical attention negates the identification effort.

Background

To minimize the time lapse between the identification of a child at risk and the provision of appropriate attention, efficient and effective administrative procedures are needed.

Procedures

Procedures were developed to inform the nursing and the speech and hearing personnel within two weeks of the conclusion of testing as to the performance of each child. Scheduling constraints restricted the time available for testing per town to a maximum of two weeks. Therefore, the greatest time lag between the initial screening of a child and the presentation of his results was approximately four weeks.

Measures

Measures were made of the time-lag between the completion of testing and the presentation of the individual test results to the responsible district personnel.

Goal

The goal was that no more than fourteen calendar days elapse between the completion of testing and the presentation of results.

AN APPROACH TO THE PROBLEM

PERSONNEL

The TAMI project was administered by representatives from six school districts in cooperation with the members of the TAMI staff. Each participating district had a central coordinating committee composed of at least one administrator, a representative of the speech and hearing staff, and a representative of the nursing staff. Among the committee's responsibilities were: scheduling of the test days and times, transferring of equipment between schools, coordinating with school principals, arranging for training sessions, preparing parental-release forms, and arranging for and supervising the testing and volunteer personnel.

The TAMI staff consisted of a director, assistant director, and several consulting audiologists. Each member of the staff held at least the academic requirements for the Certificate of Clinical Competence in Audiology from the American Speech and Hearing Association. These individuals worked in conjunction with a facilities coordinator who informed the project staff of the physical arrangements and testing constraints at each of the schools. The staff's primary responsibility was to provide the instruction and supervision necessary to assure uniformity in testing procedures within and between districts.

Each district provided nursing and speech and hearing personnel to perform the testing. Aides and volunteers were also provided to record data, manage traffic, arrange facilities, and sterilize eartips. The staff of each district was divided into teams, and usually three

ADMINISTRATIVE ORGANIZATION

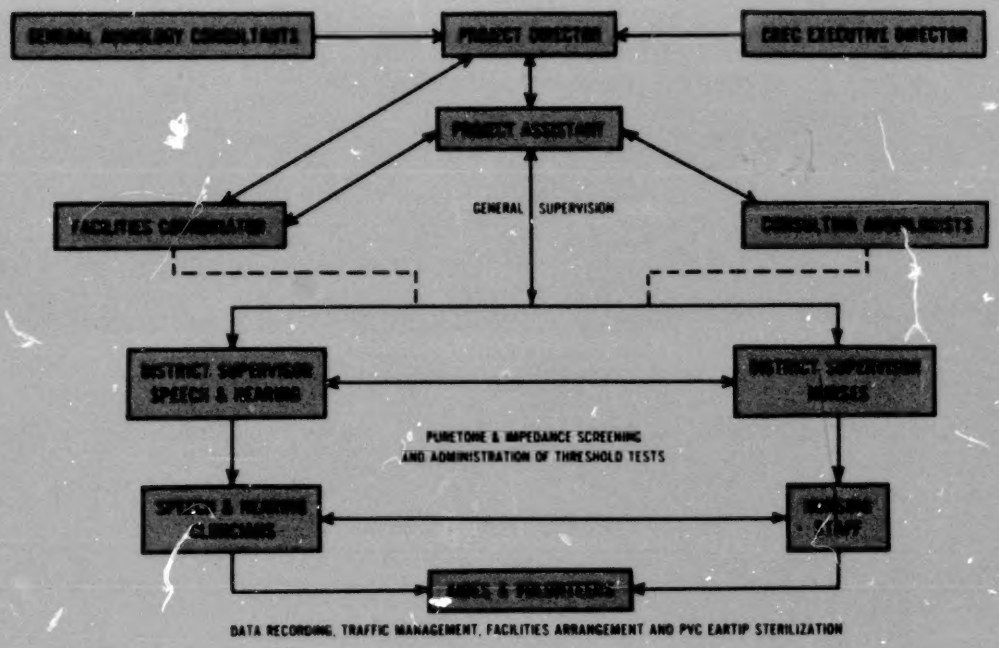

GENERAL SUPERVISION
PURETONE & IMPEDANCE SCREENING
AND ADMINISTRATION OF THRESHOLD TESTS
DATA RECORDING, TRAFFIC MANAGEMENT, FACILITIES ARRANGEMENT AND PVC EARTIP STERILIZATION

FIGURE 3.1

teams operated simultaneously in one school for initial screening but in different schools for rescreening. Figure 3.1 illustrates the administrative organization of the project, and Table 3.1 presents the numbers of persons involved from each of the participating districts.

SUBJECTS

A total of 8,528 children from 32 elementary schools, representing six Connecticut towns, participated in the project. The towns and schools were selected to represent a wide range of urban-suburban and rural populations, ethnic-racial distributions, and socio-economic levels. The specific choice of schools was made by the local supervisory and administrative personnel in cooperation with the project director.

All children in the Kindergarten, first, second, and third grades from the participating schools, who were present on the days of testing, were included in the study. In addition, some fifth-grade pupils and a few pre-school and fourth graders were also included. In accordance with local policy, parental permission was usually required. With the exception of those having known hearing problems, all children received audiometric and tympanometric screenings. Those having a record of myringotomy with tube insertion received only puretone screening and those with known sensori-neural losses received only tympanometric screening. Of the total screened, 7,928 received both puretone and tympanometric screenings, 512 received only a puretone screening and 88 received only a tympanometric screening. Tables detailing the population by type of test, town, grade and ethnic group are presented in Appendix I, Table 7.1.

PARTICIPATING PERSONNEL

School District	Speech & Hearing Clinicians	Nurses	Volunteers
1	8	6	72
2	7	4	75
3	10	10	45
4	16	3	53
5	5	5	65
6	13	15	42
Totals	59	43	352

TABLE 3.1

EQUIPMENT

At least one week before testing began in a district, an initial calibration check of all puretone audiometers was made by project personnel to determine that the units met ANSI 3.6-1969 specifications for frequency, intensity, and attenuator linearity. In addition, all audiometers were evaluated subjectively as to their mechanical and electrical integrity. During testing, all audiometers were checked daily for mechanical and electrical integrity, and were rechecked for intensity and linearity if validity were suspect.

The audiometer calibration equipment consisted of a Bruel and Kjaer (B&K) Type 2209 Impulse Precision Sound Level Meter, a model 1613 Octave Band Filter, a Type 4152 Artificial Ear, a Type 4144 Condensor Microphone, and a General Radio Model 1192B frequency counter. Intensity accuracy of the sound level meter was checked with a B&K Type 4220 pistonphone. Samples of the calibration forms are included in Appendix III, Section 9.7.

Environmental noise measurements in the rooms used for puretone testing were made with a B&K Type 4144 condensor microphone, a Type 2209 Impulse Precision Sound Level Meter and a Type 1613 Octave Band Filter. To reduce vibration bias, the equipment was mounted on a B&K tripod Type 0049. The measurements were made at the approximate location of a child's ear during testing. A copy of the form used for recording the noise level measures is found in Appendix III, Section 9.8.

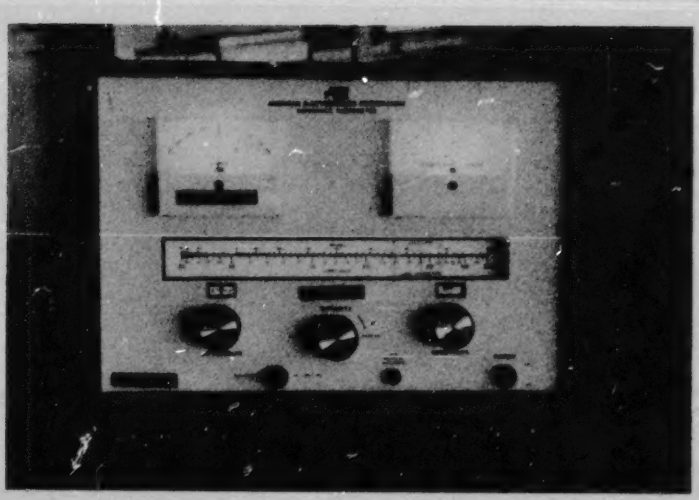
Four American Electromedics (AE) Impedance Audiometers were used during the project, two AE model 81's and two AE model 83's. To produce permanent tympanograms, each impedance audiometer was electrically

coupled to an AE model 612 dedicated XY Recorder. At most, three sets of equipment operated simultaneously on any one day. Typically, the same impedance audiometer and recorder were paired together.

A variety of makes and styles of eartips were used for procuring a hermetic ear-canal seal. Jerger (1970), in a study of 400 patients, discontinued the use of hard rubber tips in the favor of silicon tips and found that the latter type facilitated the establishment of an adequate seal. Richards and Kartye (1973) used soft plastic, hard plastic and foam eartips. The results indicated comparable measurements of acoustic impedance compliance and auditory reflex thresholds with all three types of tips. Soft and hard plastic, however, tended to produce more reliable compliance on test-retest than did the foam type. Brooks (1971a) reported that the depth of insertion of the tip into the external auditory canal had no discernable influence on compliance values.

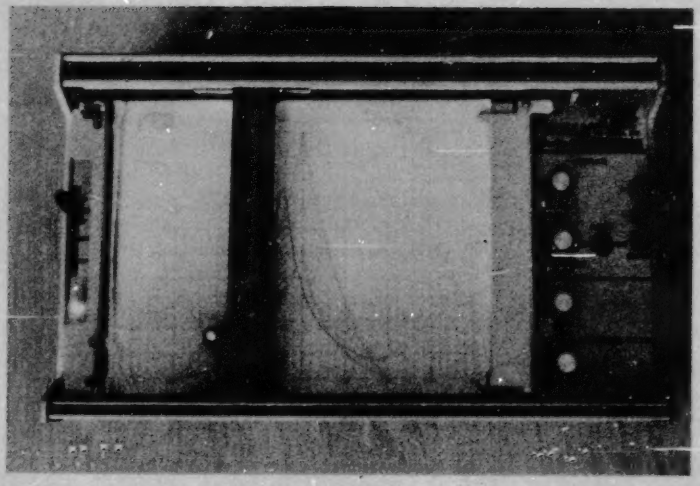
TESTING FACILITIES

With the understanding that the TAMI model was for mass screening to be conducted within a limited time period, the supervisors in each district were provided with a set of guidelines for the selection of facilities and instructed to choose rooms which could accommodate three tympanometry and four puretone screening stations simultaneously (cf., Appendix II, Section 8.1). A project consultant then visited the schools in each district to assist in the final selection of appropriate rooms. Speech clinicians and nurses, under the direction of the school's principal, assisted in the selection.



American Electromedics Model 81
Impedance Audiometer.

Bruel & Kjaer Type 2209
Impulse Precision Sound
Level Meter.



American Electromedics Model 612
Tympanograph Recorder

Room Size

In order to accommodate three tympanometry screening stations simultaneously, a room approximately 40' x 60' was selected. Generally, this was a gymnasium, auditorium, cafeteria, or multi-purpose room. For puretone screening, a facility was chosen that provided adequate space for four portable audiometers, such as a library or large classroom. Occasionally, the puretone facility was the auditorium stage which was separated from the main room by panels or curtains.

Location of Room

Care was taken to locate the puretone testing in a room relatively free of environmental noise. Thus, the room chosen was as far as possible from stairways, playground, Kindergarten, cafeteria, or the gymnasium. Some of the facilities utilized for puretone testing would be described as adverse. Nevertheless, frequent monitoring of ambient noise levels using a B&K Type 2209 sound level meter established the adequacy of the environments for puretone testing at the intended screening frequencies: 1000, 2000, and 4000 Hz.

Since tympanometry is essentially unaffected by ambient noise, the requirements for this room's location were far less critical. However, for efficient traffic management, generally the two rooms were in close proximity.

Electrical Requirements

Sufficient electrical outlets were needed to meet the power requirements of seven pieces of equipment in the tympanometry room

and four pieces of equipment in the puretone facility without overloading any single circuit.

Furniture

Each of the three tympanometry stations required one large table (approximately 3' x 6') and four chairs. Each of the puretone testing stations required one large table (or two desks) and two chairs. Additionally, two 3' x 6' tables with chairs were needed for registration, form retrieval and miscellaneous data recording.

PROJECT EXECUTION

Coordination Phase

Several coordination and planning meetings were held by the project's central staff with the districts' representatives before any testing was begun. Packets containing sample forms for schedule development and test administration procedures were distributed at these times. Examples of these forms are found in Appendix III, Section 9.9. Additional meetings were held by the project director with school administrators to explain the purpose of the project and the procedures involved in puretone and tympanometric screening.

Training Phase

A one-day workshop was held in each district approximately one week prior to the initiation of screening. Attendance was required of all speech and hearing clinicians, nurses, and parent volunteers to be involved in the project. In all, 59 speech clinicians, 43 nurses and 352 parent volunteers participated in the workshops (Table 3.1).

As an introduction, the director explained the rationale for the project, the roles of the participating personnel, and the anticipated results. A slide presentation on puretone screening, tympanometric screening, and data recording procedures was used to clarify the roles of the testers and volunteers and to present some of the specific requirements of each task. The remainder of the first session was spent attempting to develop uniform puretone screening and threshold procedures. To reinforce the desired puretone testing protocols, mimeographed outlines of the procedures to be followed were distributed and time was allotted for demonstration and questions and answers about the procedures (Appendix II, Sections 8.2-8.4).

The purpose of the second session was to familiarize the testers with the equipment employed in tympanometry and to standardize procedures. A presentation on the theory of tympanometry was followed by a demonstration of tympanometric screening and individual practice with the equipment. Again, a mimeographed outline, detailing the standardized procedure, was distributed (Appendix II, Sections 8.5-8.7).

Testing Phase

Personnel. All screening was the responsibility of the speech clinicians and nurses of the local district, under the supervision of the three consulting audiologists on the project staff. Data recording, traffic management and eartip sterilization were the responsibilities of parent and/or student volunteers. Noise measurements in the puretone screening areas were the responsibility of project audiologists.

Scheduling. The screening was carried out within each district during a two-week period, and within a given school within two days. On the initial day approximately 300 students were screened audiometrically and tympanometrically at a rate of about one per minute using three tympanometers and two puretone audiometers simultaneously. The order of testing between puretone and tympanometry was reversed for approximately one half of the total tested. All absentees and those failing to meet the pass criteria on either puretone or tympanometric screening were re-scheduled for testing on the second day. All children who failed the puretone screening on the second day received an immediate threshold test.

Melnick, et al. (1964), and Wilson and Walton (1974) have demonstrated that the number of first-screen failures on puretone audiometry may be reduced 50 percent by rescreening. Thus, to reduce the number of over referrals, the rescreening was accomplished usually within three days after the initial screening. In two districts, however, the first and second screening days were separated by seven days in order to sample the screen/rescreen reliability of tympanometric results across a longer span of time. In these latter two districts, repeat tympanograms were recorded for all first and second graders.

Tests Completed. All testing was conducted between February 1st, and June 15th, 1974. During this period more than 21,000 tests were administered in a total of 57 days. Of the total tests administered, there were approximately 11,000 puretone screening tests, 10,000 tympanometric screening tests, and 1,000 puretone threshold tests. The mean number of puretone screening tests administered per test

day was 196, with a median of 199 and a modal value of 274. The mean number of tympanometric tests administered per test day was 190, with a median value of 191 and a modal value of 274. The mean number of threshold tests administered per day was 27 with a median of 26 and a modal value of 26.

Puretone Screening. All audiometers were turned on at least one half hour prior to the initiation of testing and were checked for mechanical and electrical integrity. Puretone screening procedures were the same on both the initial and the rescreen days.

Puretone screening consisted of checking for a response to puretones of 1000, 2000 and 4000 Hz in each ear at a level of 20 dB HL at 1000 and 2000 Hz, and 25 dB HL at 4000 Hz (re: ANSI standards). In practice, the testers were instructed to screen at 20 dB HL at all frequencies. If the child did not respond to 4000 Hz at that level, the level was then increased to 25 dB HL to determine whether the child passed or failed that frequency.

After instructing the child as to the method of response, the earphones were positioned on the child's head and he was trained to respond to a 1000 Hz tone at 40 dB HL. When necessary, reinstruction

was provided. With rare exception, the children were easily trained. After training, the tonal intensity was quickly reduced to 20 dB HL and the tone presented for 2-3 seconds. The basic procedure was then repeated for 2000 and 4000 Hz in the same ear, and then for 4000, 2000 and 1000 Hz in the opposite ear. A test ear-effect was controlled for by alternating the initial test-ear of each successive child.

Since three presentations were permitted at each frequency, failure at one frequency was defined as a lack of response to at least two-of-three tonal presentations. Failure to respond to any one of the test frequencies, in either ear, necessitated a rescreening. Failure to meet the same criteria at rescreening necessitated a threshold test. All rescreening examinations were performed within seven calendar days of the original screening, and all threshold tests were performed on the same day as the rescreening.

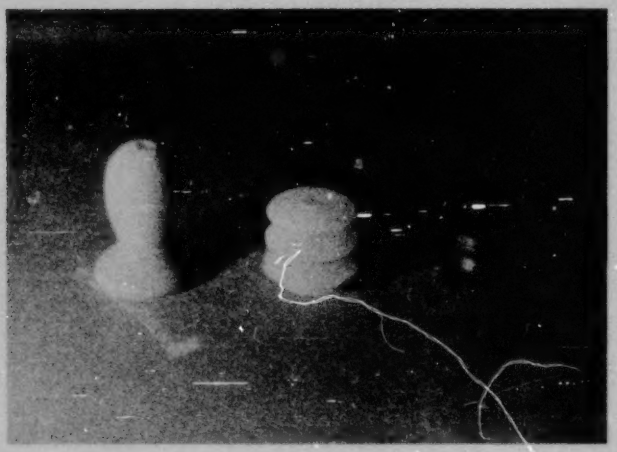
Tympanometric Screening. Three tympanometric test teams operated simultaneously in a given school. Each team consisted of two testers drawn from the districts' nursing and speech and hearing staffs, one parent volunteer for data recording, and a supervisor from the project staff. One tester obtained an ear-canal seal while the other operated the tympanometric equipment. By this means it was possible to test one child per minute per team and to provide opportunity for each tester to gain experience and facility in all facets of tympanometric screening. Other volunteers were used for traffic management, data checking, and sterilization of the eartips. The equipment was arranged and calibrated daily by the testers and the project staff.

Each child to be tested was directed individually and arbitrarily by a volunteer to one of the three teams. One tester examined the child's ears for superficial wax and estimated the size of the child's external auditory canal. Excessive wax at the lateral margin of the canal was removed with sterile swabs. No attempt was made to remove wax deep within the canal, or even to determine if it was present. There was no systematic control for the order of ear to be tested. A sterile eartip was placed on the tympanometer probe and a hermetic seal attempted.

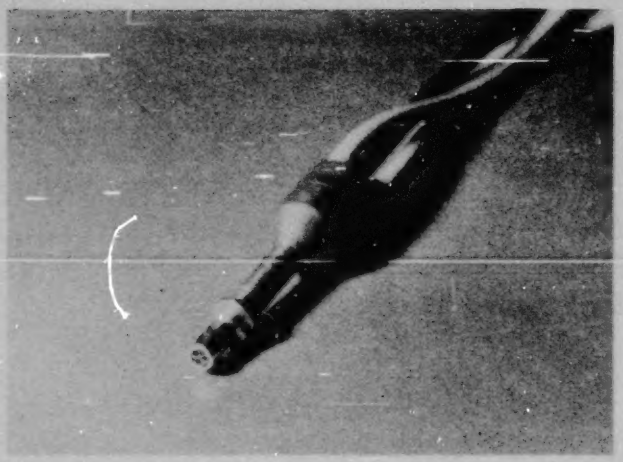
Almost always an air-tight seal was affected immediately. A seal was considered acceptable if the needle of the manometer held at +200, or decreased by no more than 20 mm H_2O within ten seconds, after introducing +200 mm H_2O equivalent air pressure into the canal. When

difficulty was encountered in obtaining a seal, different sizes and styles of eartips were tried and the equipment checked for air-pressure leaks. If a seal could not be obtained within 60 seconds, "could not test" was recorded for the particular ear(s) and the child was scheduled for re-examination.

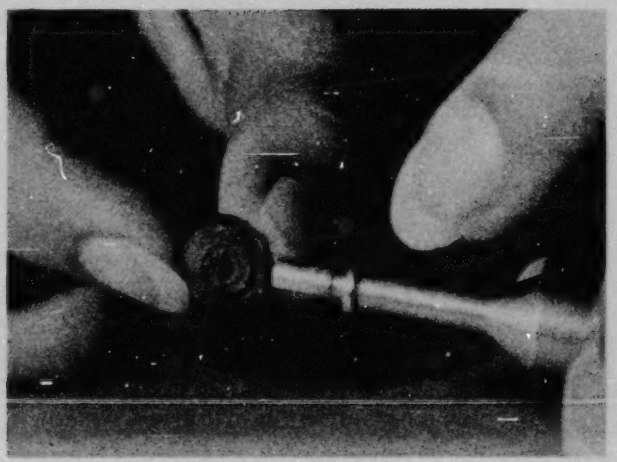
Tympanometry Pass/Fail Criteria. Initial pass/fail criteria used during the project were based on a review of data in the literature where the selected pressure cut-off values were found to range from -80 mm of water pressure to -200 mm, depending upon the population studied. Renvall, et al., (1973) in a dual pilot study of 200 ears of seven-year-olds and 206 ears of ten-year-olds, considered a tympanogram as pathological when the peak occurred at pressures more



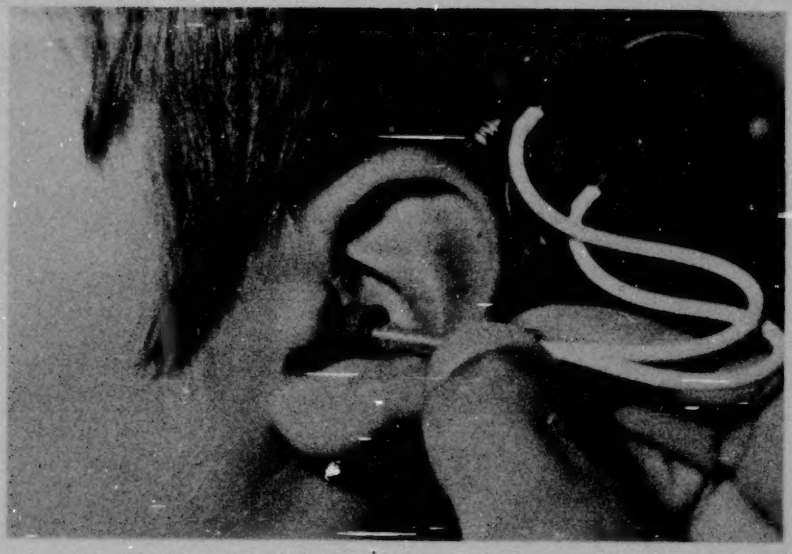
Various sizes and shapes of eartips permit an hermetic seal in the ear canal.



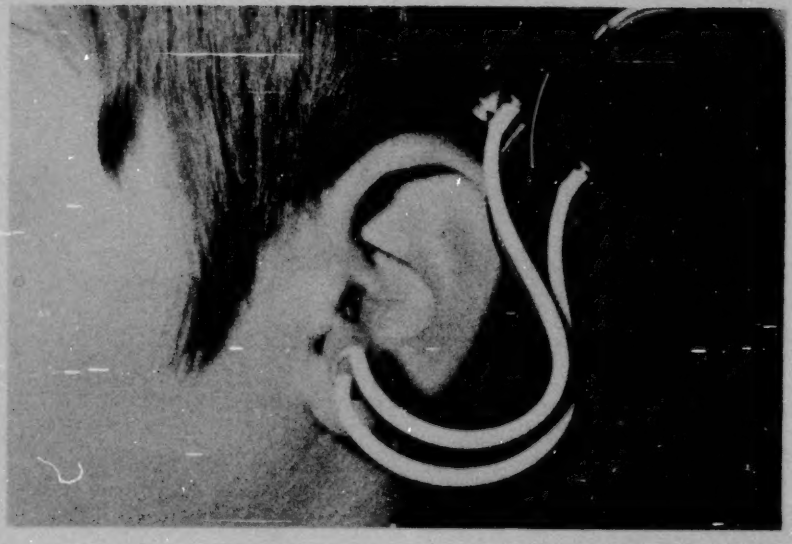
A low frequency tone and air pressure/ vacuum are conducted via a metal probe.



Sterile eartip is placed on the metal probe.



Probe with tip is inserted in the ear canal.



With the probe in place, tympanometry testing takes only a few seconds.

negative than -80 mm of water. Feldman (1974, private communication) recommends -80 mm as the pass/fail point. Among the authors using -100 mm are Jerger, Jerger and Mauldin (1972), Porter (1974), Jerger (1970), Harker and Van Wagoner (1974), McCandless and Thomas (1974), and Bluestone, Beery, and Paradise (1973). Randolph (1974, private communication) recommends the use of -160 mm, while Brooks (1969), in a study of 1053 children from ages 4-11 years, used -170 mm.

Reviewing the works of McCandless and Thomas (1974), Brooks (1973) and Randolph, et al., (1974), among others, it was noted that generally 81 percent agreement between otoscopic and impedance results had been

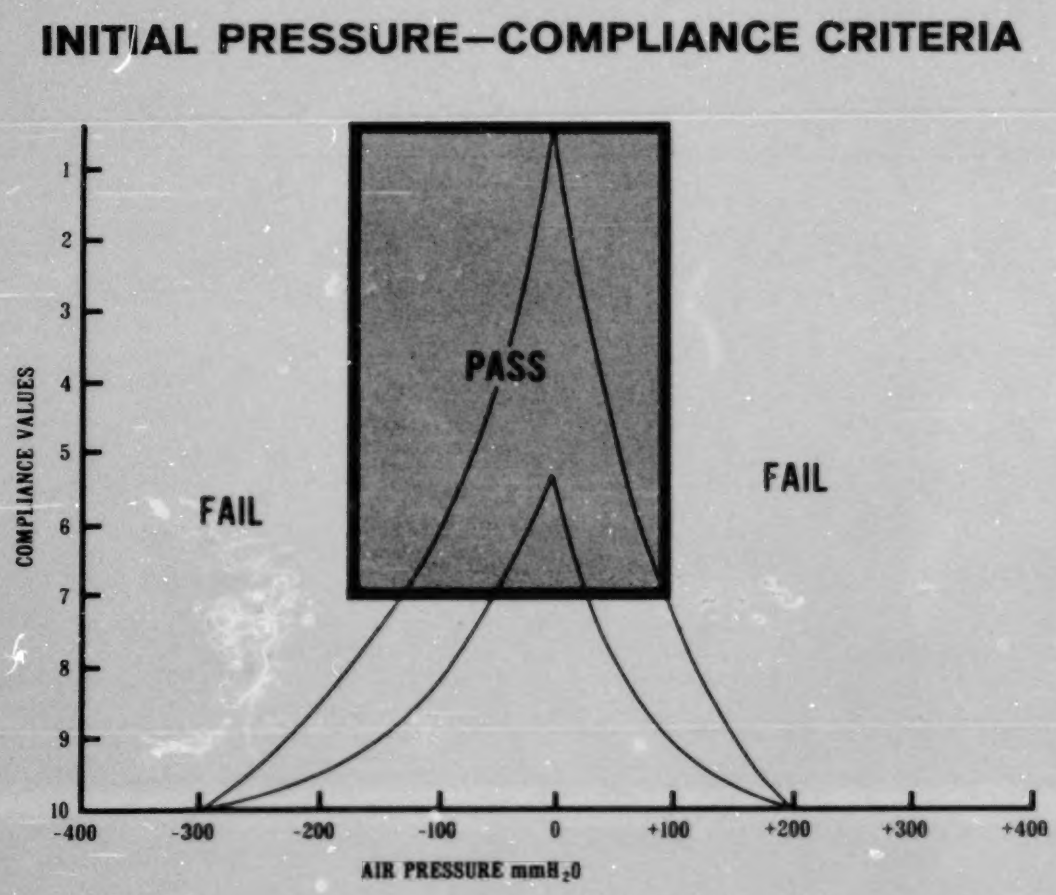
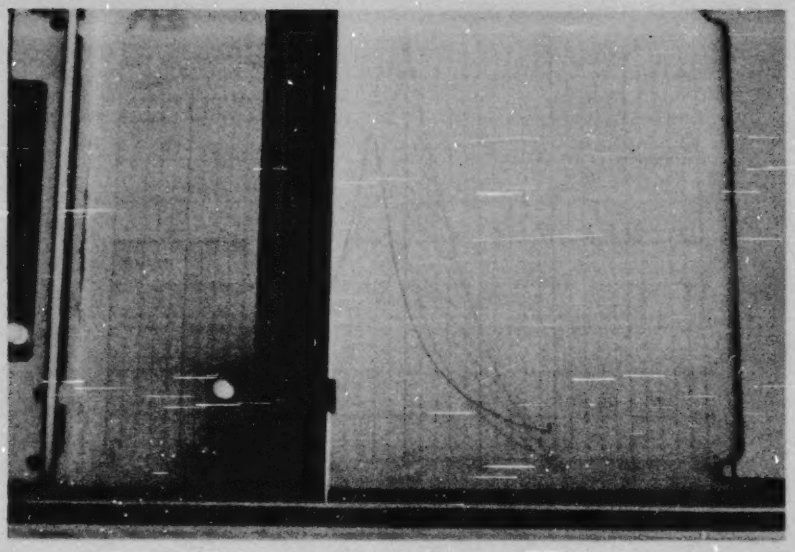


FIGURE 3.2

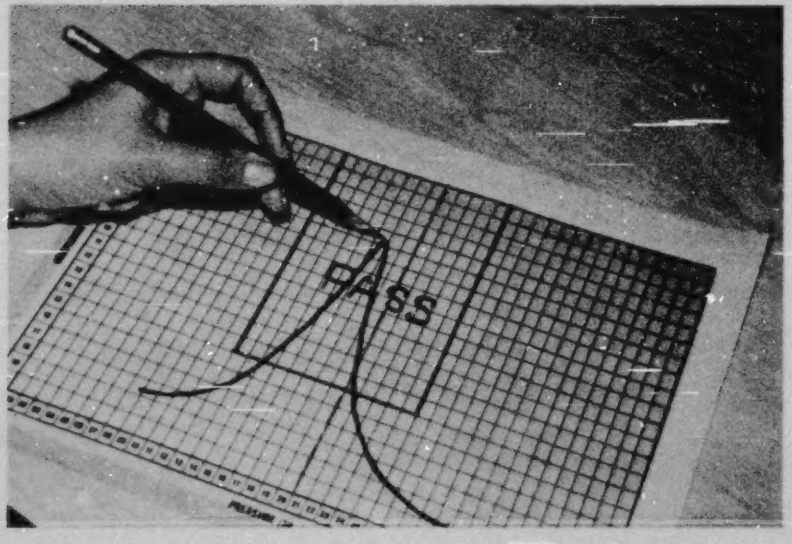
obtained using air pressure failure criteria between -100 and -200 mm H_2O. Considering this agreement between otoscopy and impedance audiometry, the uncertainty of accomplishing logical referrals for those identified, the seasons of the year during which the project was to be conducted, and the mass-screening nature of the project, -160 mm and +100 mm H_2O were chosen as conservative first-approximations for air pressure pass/fail cut-off values. Based upon Randolph's data, an arbitrary first-approximation failure criterion for compliance was set at "7" (on the American Electromedics scaling). These values are shown in Figure 3.2 by a solid rectangle together with the conventional AE pass/fail figure. It was intended that these values be re-examined at the conclusion of the project and that specific recommendations be made for pass/fail criteria to be used with tympanometric screening programs in schools.

Tympanometry Data Recording. Data were recorded which identified the child, date and type of test, the equipment utilized, the approximate pressure and compliance values for the peak of the tympanographic plot, the general shape of the plot, and an overall conclusion about the results for each ear. The general conclusion of "pass," "fail," "inconclusive," or "could not test" was the basis for deciding if rescreening were necessary.

A gridded acetate overlay was placed on the subject's tympanograph for determining the pressure and compliance coordinates of the peak and whether the tympanograph met the pass criteria. To facilitate use, the overlay divided the pressure scale (horizontal axis) into 40



A chart of the middle ear pressure-compliance relationships is produced on the recorder.



Classification of the tympanometry results is facilitated with a gridded sheet placed over the chart.

regions of 20 mm (H_2O) each and the compliance scale (vertical axis) into 20 regions of 0.5 units each (American Electromedics scaling). A set of four digits (two for pressure and two for compliance) identified the cell within which the peak was located. For reporting purposes all values were converted back into their respective pressure and compliance units. Difficult to evaluate tympanographs were referred to the consultant in charge of the particular team.

Tympanographic configurations considered distinctive enough for classification were "flat," "rounded," "peaked," and "off-limits" (Figure 3.3). Hyper-compliant ears ("off-limits") were given a compliance value of "01" and a pressure value equal to that obtained when the sensitivity of the impedance audiometer was reduced ("Ad" position)

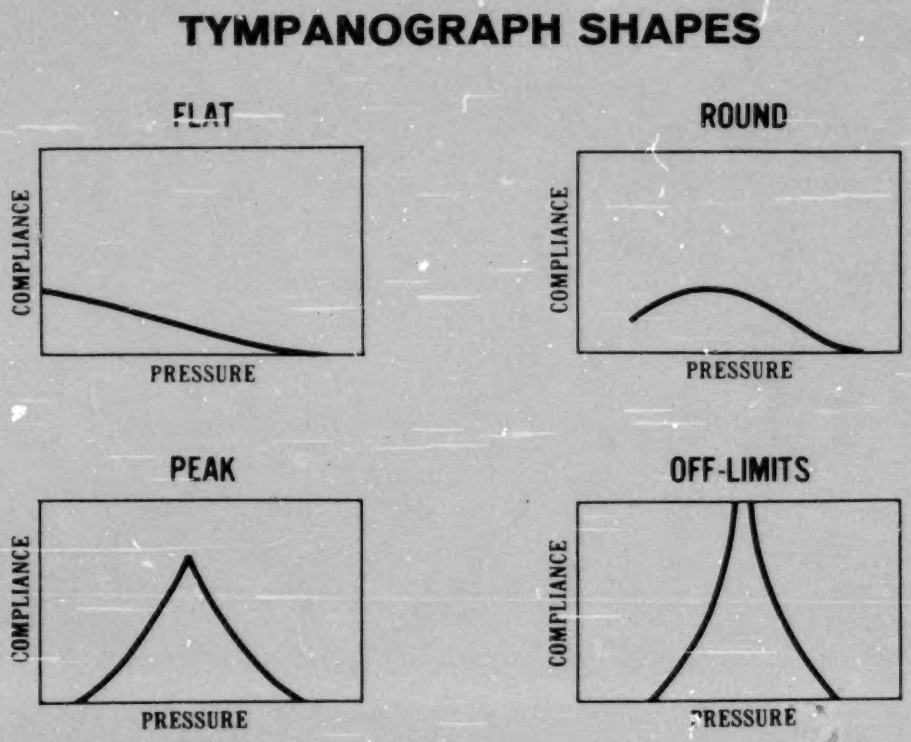


FIGURE 3.3

and the tympanometric testing of the ear repeated.[1] "Flat" and "rounded" tympanographs were assigned pressure and compliance values most representative of the highest excursion of the pen (i.e., the lowest obtained compliance value).

Children not passing the tympanographic screening in both ears on the initial day received a complete tymparometric rescreening on the second day. First-day absentees, and those for whom the results were "inconclusive," were also scheduled for testing on the second day.

Audiometric Threshold Testing. All who failed the puretone screening on the second test day received an immediate threshold test on the ear(s) not meeting the screening criteria. Testers were instructed to obtain thresholds above 10 dB HTL at 500, 1000, 2000 and 4000 Hz using the Hughson-Westlake technique (Carhart and Jerger, 1959).

The threshold test results at each frequency and the speech-frequency average (500, 1000 and 2000 Hz) were recorded for each tested ear. A pass/fail decision for each ear was based on the threshold results obtained for each of the test frequencies employed. An ear "failed" if a threshold greater than 25 dB HTL was obtained at 4000 Hz, or if thresholds of 15 dB or greater were obtained at two or more of the other test frequencies.

Daily Calibration. Each day the puretone audiometers received a gross calibration check after being allowed to warm up for at least

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[1] A peak was observed in every instance when the testing was repeated with reduced sensitivity.

thirty minutes. The testers were instructed to recheck the calibration if during the day two or more consecutive children failed screening at a particular frequency. Suspect audiometers were either recalibrated or replaced with units known to be in calibration.

The manufacturer's recommended procedures for calibrating the impedance audiometers were followed after the equipment was allowed to warm up for at least thirty minutes. Each impedance audiometer was aligned with its associated X/Y recorder prior to the testing and whenever the recorder pad had to be replaced. To guarantee equivalent results between the sets of impedance audiometers, between-set comparisons were also done daily prior to the testing. Several pressure calibrations were made daily. These procedures, as well as the correction of minor maladjustments in the equipment (e.g., air pressure leaks due to cracked rubber tubes) were performed by the testers under the supervision of the project staff.

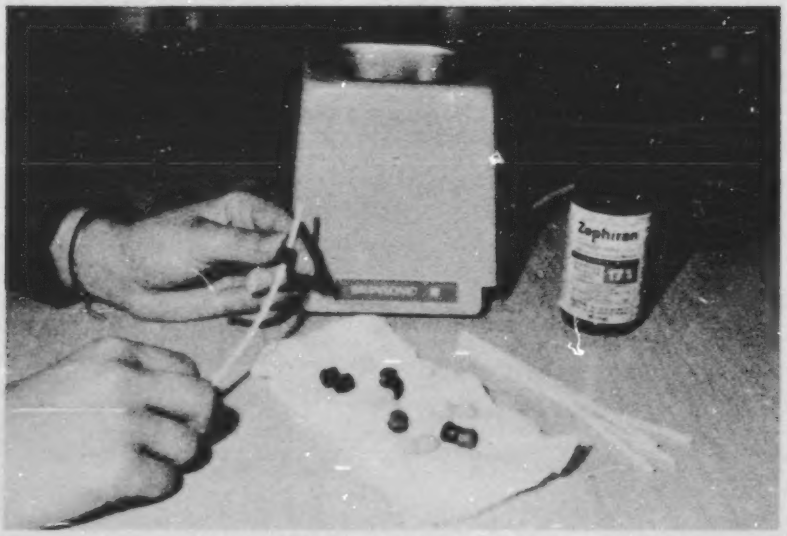
Noise Measurement. Since none of the puretone testing rooms were sound treated, periodic environmental noise measurements were made to assure that the level of background noise remained below criteria. Measurements were made using a B&K Model 2209 impulse precision sound level meter and a Model 1613 octave filter. The equipment was mounted on a tripod to reduce vibration bias and then placed at a position approximating the child's ears during testing.

Measurements were taken at least three times at each test site: once before the testing, once at the mid-morning recess, and once during the early afternoon when the children were often on luncheon

breaks. Thus, the measured noise levels represented both the ideal and the worst possible conditions under which tests might be conducted. Measurements were made also when any new extraneous noise sources (e.g., external construction equipment, lawnmowers) were operated in the vicinity. Whenever the measured noise exceeded 52 dBA, the testing was halted until the noise was reduced.

Measurements were made on the linear, dBA, and dBC scales and at 500 Hz. The median noise measurements for each site are found in Appendix I, Table 7.5.

Eartip Sterilization Procedure. As a protection against the transmission of bacteria from child-to-child, all soiled eartips were placed in a sonic cleaner (Hal-Hen Model 2189 T-3) and agitated for



five minutes in a fresh, one-percent solution of Zephiran Chloride. The tips were then rinsed in a clear water bath and blotted between towels to remove excess water. Next, pipe stem cleaners were used to remove any water bubbles remaining within the tip, and, finally, the tips were dried with a commercial hair dryer. Thorough drying of the tips was necessary to maintain proper functioning of the tympanometric equipment.

Follow-Up Phase

Data Distribution. Following the completion of testing in a district, the information marked on the TAMI data forms was read optically onto magnetic tape for computer analysis. The results for each child were listed alphabetically by school and grade to facili-

tate use within the district. The typical time lapse between the completion of testing and the delivery of the results to a given town was two and one-half weeks. Subsequent consultation with each district was provided by the project staff to aid in the interpretation and utilization of the data.

Suggested Follow-Up. Follow-up suggestions for each child were included on the student listing. Examples of these suggestions are found on the sample print-out sheet (Table 4.2, 4.3a, b). Separate statements for educational and medical attention were included for the puretone air-conduction screening, the tympanometric screening, and the puretone threshold testing. Sample referral forms and an explanatory note on tympanometry were also provided for distribution to the individuals and/or agencies to whom the identified children were to be referred. Ultimate decision on whom to refer was left to the district personnel.

Data Analysis. For evaluation of the model, the data were analyzed by town and then aggregated across the six towns. The results of the various tests were compared with other known information on each child (i.e., age, sex, grade, known hearing status, ethnic background, and the number of absences accumulated in the school year). Attitudes towards tympanometry and the model in general were sampled via questionnaires sent to the speech and hearing clinicians and to the nurses involved in the testing and to representative school and district administrators.

FINDINGS OF THE STUDY

As a feasibility study from which a variety of professionals might profit, certain guidelines were established for examining the data. First, hoping that the results might be useful to school audiologists and/or speech and hearing clinicians, the results are presented in readily available tables and figures. Second, we tried to avoid examining the data more closely, or generalizing more broadly, than was justified by either the experimental design or by the experimental controls. Third, wherever possible, extensive tables, descriptive materials, and sample forms are relegated to the Appendices. For comparative purposes, puretone screening, puretone threshold, and tympanometry results are presented simultaneously by topic. Findings unique to a particular test are then presented, followed by a proposed set of tympanometry pressure and compliance values for general screening.

GENERAL ANALYSES

Pass/Fail Ratios

The pass/fail ratios obtained for all of the subjects for each of the tests are presented in Table 4.1. Children who failed the initial screening and subsequently passed the rescreen were counted as "pass." As shown, 10.8 percent failed the puretone screening and 91.7 percent of those failed the threshold examination. Based on the total receiving a puretone screening, 9.6 percent failed two screening tests and a threshold examination. Approximately 20 percent of those

PASS-FAIL RATIOS PER TEST

		PASS		FAIL		
	No. Tested	No.	%	No.	%	
PURE TONE SCREEN	8440	7524	89.2	916	10.8	
THRESHOLD	881	73	8.3	808	91.7 (9.6)	=% OF TOTAL GROUP (N=8440)
TYMPANOMETRY	8016	6391	79.7	1625	20.3	

TABLE 4.1

receiving tympanometric testing failed to meet the pass criteria.

Initial screening versus rescreening performance for puretone testing and tympanometry are emphasized in Figure 4.1. As shown, 77.9 percent passed the initial puretone screening and 71.0 percent passed the initial tympanometry screening. The number failing initially but passing the rescreening was 11.3 percent of the total for puretone screening and 8.7 percent for tympanometry. Almost twice as many (20.3 percent) failed two tympanometry screenings as failed the puretone screenings (10.8 percent). Two-ear failures were more than twice as common for tympanometry (11.9 percent) as they were for puretone testing (4.6 percent).

Computer-prepared listings of the children's test performance, together with suggested referral statements, were supplied to the local nursing and speech and hearing personnel. Samples of the listings (with names censored to preserve confidentiality) and the associated legend are presented in Tables 4.2, 4.3a and 4.3b.

SCREEN-RESCREEN RESULTS

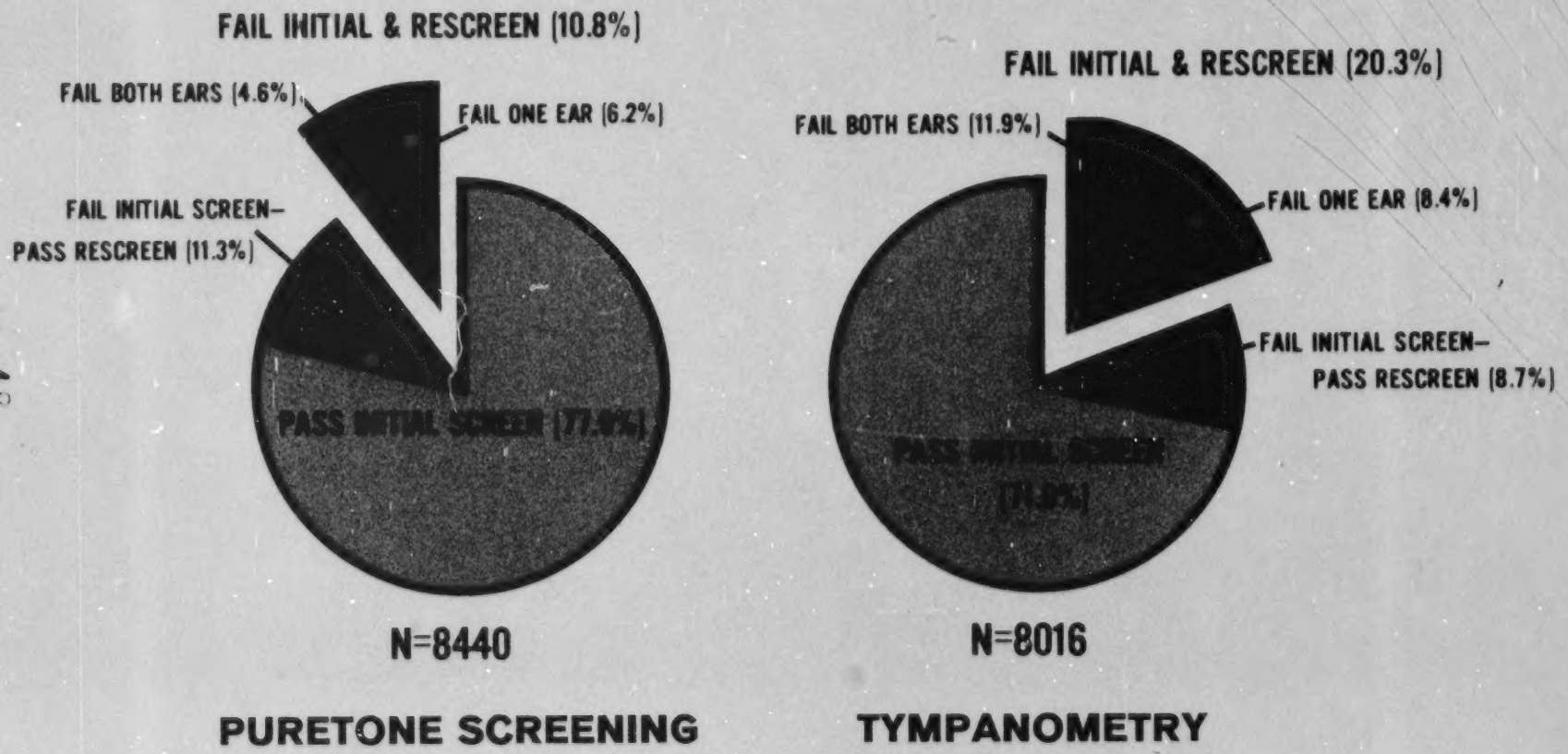


FIGURE 4.1

LEGEND FOR UTILIZING STUDENT LISTING OF TEST RESULTS FROM PROJECT TAMI

* *

```
NAME - LAST, FIRST, MI
STU NUM    (STUDENT NUMBER) TAMI-ASSIGNED NUMBER FOR PROJECT IDENTIFICATION
KS         (KNOWN STATUS OF HEAR.) 1=KNOWN LOSS 2=NO KNOWN LOSS 3=UNKNOWN STATUS
REC DATE   (RECORD - OR EXAMINATION - DATE)
TONE-L     (TONE LEFT) PURETONE SCREENING RESULTS - LEFT EAR
     5     (500  HZ) 0=NO DATA ENTRY 1=PASS 2=FAIL
     1     (1000 HZ) 0=NO DATA ENTRY 1=PASS 2=FAIL
     2     (2000 HZ) 0=NO DATA ENTRY 1=PASS 2=FAIL
     4     (4000 HZ) 0=NO DATA ENTRY 1=PASS 2=FAIL
     S     (SPARE HZ)0=NO DATA ENTRY 1=PASS 2=FAIL
     I     (INCONCLUSIVE) 0=NO DATA ENTRY 2=INCONCLUSIVE RESULTS
     C     (COULD NOT TEST) 0=NO DATA ENTRY 2=COULD NOT TEST
TONE-R     (TONE RIGHT) PURETONE SCREENING RESULTS - RIGHT EAR
     5     (500  HZ) 0=NO DATA ENTRY 1=PASS 2=FAIL
     1     (1000 HZ) 0=NO DATA ENTRY 1=PASS 2=FAIL
     2     (2000 HZ) 0=NO DATA ENTRY 1=PASS 2=FAIL
     4     (4000 HZ) 0=NO DATA ENTRY 1=PASS 2=FAIL
     S     (SPARE HZ)0=NO DATA ENTRY 1=PASS 2=FAIL
     I     (INCONCLUSIVE) 0=NO DATA ENTRY 2=INCONCLUSIVE RESULTS
     C     (COULD NOT TEST) 0=NO DATA ENTRY 2=COULD NOT TEST
TYM-L      (TYMPANOMETRY - LEFT EAR)
     R     (RESULTS) 1=PASS 2=FAIL 3=INCONCLUSIVE 4=COULD NOT TEST
     P     (PRESSURE) L=LOW N=NORMAL H=HIGH
     C     (COMPLIANCE) L=LOW N=NORMAL
     S     (SHAPE) 1=FLAT 2=ROUNDED 3=PEAKED 4=OFF LIMITS
TYM-R      (TYMPANOMETRY - RIGHT EAR)
     R     (RESULTS) 1=PASS 2=FAIL 3=INCONCLUSIVE 4=COULD NOT TEST
     P     (PRESSURE) L=LOW N=NORMAL H=HIGH
     C     (COMPLIANCE) L=LOW N=NORMAL
     S     (SHAPE) 1=FLAT 2=ROUNDED 3=PEAKED 4=OFF LIMITS
L-TH-R     (PURETONE THRESHOLD   LEFT-RIGHT)
     A     (AVERAGE) 5-1-2KHZ LEFT:  1=0-20 2=21-40 3=41-55 4=56-70 5=71-90 6=91+
     R     (RESULT) LEFT EAR: 1=PASS 2=FAIL 3=INCONCLUSIVE 4=COULD NOT TEST
     A     (AVERAGE) 5-1-2KHZ RIGHT: 1=0-20 2=21-40 3=41-55 4=56-70 5=71-90 6=91+
     R     (RESULT) RIGHT EAR:1=PASS 2=FAIL 3=INCONCLUSIVE 4=COULD NOT TEST

SPEC HANDL     (SPECIAL HANDLING) MESSAGES EXPLANATORY OF UNIQUE CIRCUMSTANCES

*****     THE FOLLOWING MESSAGES ARE PREPARED INDEPENDENTLY OF EACH OTHER    *****

PT SCRN        (PURETONE SCREEN RESULTS) SUGGESTED MANAGEMENT
     ADV EDUC       (ADVISE EDUCATIONAL PERSONNEL OF RESULTS)
     EQV FOLLOW     (TEST RESULTS ARE EQUIVOCAL RETEST PERIODICALLY)
THRES TEST     (PURETONE THRESHOLD TEST RESULTS) SUGGESTED MANAGEMENT
     ADV E-M-PR     (ADVISE EDUC AND MED PERSONNEL AND PARENTS OF RESULTS)
     EQV FOLLOW     (TEST RESULTS ARE EQUIVOCAL RETEST PERIODICALLY)
TYMP SCRN      (TYMPANOMETRY SCREENING RESULTS) SUGGESTED MANAGEMENT
     ADV MD-PAR     (ADVISE MED PERSONNEL AND PARENTS OF RESULTS)
```

TABLE 4.2

DISTRICT : [redacted] SCHOOL : [redacted] GRADE : [redacted]

RUN DATE : 74/05/31
PAGE : 7

-- NAME --	STU NUM	KS	REC DATE	TONE-L 5124SIC	TONE-R 5124SIC	TYM-L R PCS	TYM-R R PCS	L-TH-R AR	L-TH-R AR	SPEC HANDL PT SCRN	THRES TEST TYMP SCRN
[redacted]	00310145	2	05-14-74	0111000	0111000	1-NN3	1-NN3				
[redacted]	00310146	2	05-14-74	0000000	0000000	0	0			NT-PAR REQ NOT TESTED	NOT TESTED
[redacted]	00310127	2	05-14-74	0111000	0111000	1-NN3	1-NN3				
[redacted]	00310257	3	05-14-74	0111000	0111000	1-NN3	1-NN3				
[redacted]	00310147	2	05-14-74	0111000	0111000	1-NN3	1-NN3				
[redacted]	00310151	2	05-14-74	0111000	0111000	2-NN2	2-NL2				ADV MO-PAR
			05-17-74	0111000	0111000	1-NN2	2-NL2				
[redacted]	00310148	2	05-14-74	0111000	0111000	1-NN3	1-NN3				
[redacted]	00310128	2	05-14-74	0122000	0111000	1-NN3	2-LN3				ADV MO-PAR
			05-17-74	0111000	0111000	1-NN4	2-LN3				
[redacted]	00310149	2	05-14-74	0111000	0111000	1-NN3	1-NN3				
[redacted]	00310129	1	05-14-74	0000002	0000002	1-NN3	1-NN3			NT-KNOWN NOT TESTED	
[redacted]	00310150	2	05-14-74	0111000	0111000	1-NN4	1-NN3				
[redacted]	00310130	2	05-14-74	0111000	0111000	1-NN3	1-NN3				
[redacted]	00310152	2	05-14-74	0111000	0111000	1-NN3	1-NN3				
[redacted]	00310153	2	05-14-74	0111000	0111000	1-NN3	1-NN3				
[redacted]	00310154	2	05-14-74	0111000	0111000	2-NN3	2-LN3			EQV FOLLOW ADV E-M-PR ADV MO-PAR	
			05-17-74	0111000	0211000	1-NN3	2-LN3	11	12		
[redacted]	00310255	3	05-14-74	0111000	0111000	1-NN4	1-NN4				
[redacted]	00310252	3	05-14-74	0111000	0111000	1-NN3	1-NN3				
[redacted]	00310133	2	05-14-74	0111000	0111000	1-NN3	1-NN3				

TABLE 4.3a

DISTRICT : [redacted]

SCHOOL : [redacted]

GRADE : [redacted]

RUN DATE : 74/05/31
PAGE : 11

-- NAME --	STU NUM	KS	REC DATE	TONE-L 5124SIC	TONE-R 5124SIC	TYM-L R PCS	TYM-R R PCS	L-TH-R AR	SPEC HANDL AR	PT SCRN	THRES TEST	TYMP SCRN
ABBE	00310001	2	05-14-74	0111000	0111000	2-NN3	1-NN3					
ANN			05-17-74	0111000	0111000	2-LN3	1-NN3					
BELL FRONTE	00310002	2	05-14-74	0111000	0111000	1-NN3	1-NN3					ADV MD-PAR
BIATROW	00310003	2	05-14-74	0111000	0111000	2-NN2	2-NN2					
			05-17-74	0111000	0111000	1-NN3	2-NL3					
BOSC	00310004	2	05-14-74	0111000	0111000	2-LN3	2-NN3					ADV MD-PAR
			05-17-74	0111000	0111000	2-LN3	1-NN3					
BOYE	00310005	2	05-14-74	0111000	0111000	1-NN3	1-NN3					ADV MD-PAR
BOYE	00310006	2	05-14-74	0111000	0111000	2-LN3	2-NN3					
			05-17-74	0111000	0111000	2-LN3	1-NN3					
CATALDIA	00310007	2	05-14-74	0211000	0211000	2-LN2	2-LN3					ADV MD-PAR
			05-17-74	0212000	0211000	2-LN2	2-LN3					
CRUZ	00310008	2	05-14-74	0111000	0111000	1-NN3	1-NN3	22	22	ADV EDUC	ADV E-M-PR	ADV MD-PAR
DIAN	00310009	2	05-14-74	0111000	0111000	1-NN3	1-NN3					
EASTMAN	00310010	2	05-14-74	0111000	0111000	1-NN3	1-NN3					
GRIFFIN	00310231	1	05-14-74	0111000	0111000	2-LN3	2-LN2					
			05-17-74	0111000	0212000	2-NN3	2-LN1					
HAWLEY	00310012	2	05-14-74	0111000	0112000	1-LN3	2-NN3	12	22	EQV FOLLOW	ADV E-M-PR	ADV MD-PAR
			05-17-74	0000000	0000000	0	0					
HECK	00310013	2	05-14-74	0111000	0111000	1-NN3	1-NN3		ABS ONCE	ADV EDUC		ADV MD-PAR
HOLCOMB	00310014	2	05-14-74	0111000	0111000	1-NN2	2-LN3					
			05-17-74	0111000	0111000	1-NN3	2-LN3					
HUNDLEY	00310015	2	05-14-74	0111000	0111000	2-LN3	2-LN3					ADV MD-PAR
			05-17-74	1111000	0111000	2-LN3	1-NN3					
HOUSTON	00310016	2	05-14-74	0112000	0212000	1-NN2	2-LN2					ADV MD-PAR
			05-17-74	0111000	0222000	1-NN3	2-LL1					
JACOB	00310017	2	05-14-74	0111000	0111000	1-NN3	1-NN3	12	22	ADV EDUC	ADV E-M-PR	ADV MD-PAR
JAME	00310018	2	05-14-74	0111000	0111000	1-NN3	1-NN3					
JERSEREAU	00310019	2	05-14-74	0111000	0111000	2-LN3	2-LN3					
			05-17-74	0111000	0111000	1-NN3	1-NN3					
JORD	00310020	2	05-14-74	0212000	0211000	2-LL1	2-LL1					
			05-17-74	0000000	0000000	0	0					
KOZENESKI	00310021	2	05-14-74	0000020	0000020	1-NN3	1-NN3		ABS ONCE	ADV EDUC		ADV MD-PAR
			05-17-74	0111000	0111000	0	0					
KELSON	00310229	2	05-14-74	0111000	0212000	1-NN3	2-LL2					
			05-17-74	0222000	0222000	1-NN3	2-LL1					
KRTZ	00310022	2	05-14-74	0212000	0111000	2-LL1	2-LN3	12	22	ADV EDUC	ADV E-M-PR	ADV MD-PAR
			05-17-74	0111000	0111000	2-LN3	1-NN3					
LERARIO	00310023	0	05-14-74	0000000	0000000	0	0					ADV MD-PAR
									ABS BOTH	NOT TESTED		NOT TESTED

-- NAME --	STU NUM
LIND	00310001
FREDERICK	00310002
ELIZDA	00310003
HERYL	00310004
TERESA	00310005
RENDELL	00310006
STEVEN	00310007
JENNIFER	00310008
ANC	00310009
NGELA	00310010
RIC	00310231
DONALD	00310012
ABRINA	00310013
ISA	00310014
IMOTHY	00310015
ERRI ANN	00310016
TEWART	00310017
AME	00310018
ERR	00310019
ICHARD	00310020
AME	00310021
SHERRY	00310229
ERSEN	00310022
ANC	00310023

TABLE 4.3b

Grade Analysis

Performance by grade on the respective tests is shown in Figure 4.2. Improved performance with increased grade is evident for all three tests but most pronounced for tympanometry. From Kindergarten through grade five the percent failing puretone screening decreased from 17.2 to 6.6. Similar results are shown for tympanometry where the slope of the curve approaches that for puretone screening but appears to asymptote somewhere beyond the fifth grade. The implications with respect to probable middle ear pathology among the children

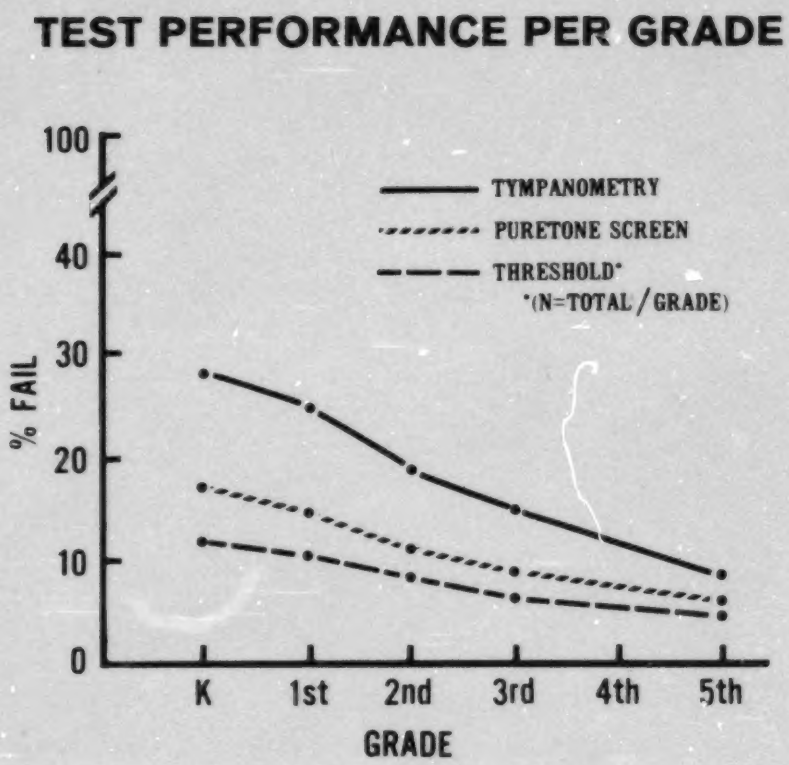


FIGURE 4.2

in any identification audiometry program are obvious. Chi-square tests between the pass/fail ratios for the respective tests and grade level were significant beyond the 0.001 level of confidence. Tables detailing the puretone and tympanometric screening results per grade and town are found in Appendix I (Tables 7.6 and 7.7).

Seasonal Effects

Testing was conducted during the second through sixth months of 1974. To examine the relative seasonal effects, the data are presented in Figure 4.3 by town in the order tested. Children from the three towns tested during the late winter months manifested a higher percent failure on tympanometry than did those tested in the spring months. From February through March, an average of 24 percent failed in the three towns tested. Two weeks passed before the next town was tested, and the percentage then dropped to a mean of 17 percent for the mid-April to early-June period. Graphs of the compliance and pressure values obtained during the two seasons are presented in Figure 4.4. Means for the respective distributions are shown by lines drawn perpendicularly to the respective axes. Not only did middle ear compliance increase during the spring compared to the winter months, but so also did middle ear air pressure.

In contrast to the change in performance observed for tympanometry, puretone screening results remained essentially the same throughout the period of testing. Although sampling was conducted during a period when upper respiratory infections seemed the rule, and again during a significant allergy season, virtually no difference was detected in the

RESULTS BY TOWN IN ORDER TESTED

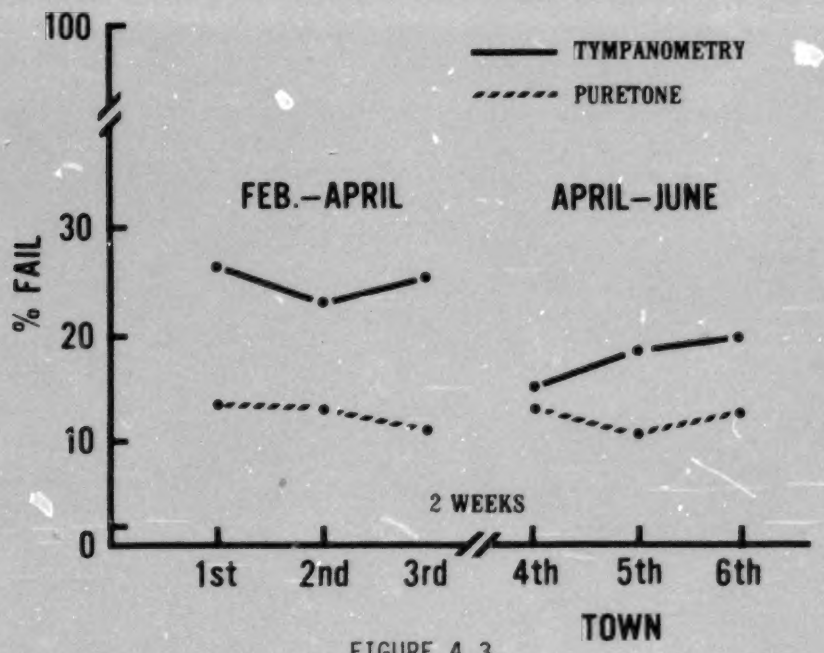


FIGURE 4.3

percentage failing puretone screening as a function of the month of testing. The percentage of children at any one time who evidenced an educationally significant hearing loss due to colds or allergies did not change, despite the increased prevalence of middle ear pathologies during the winter as evidenced by tympanometry.

Analysis by Ear

There were no observable ear-effect trends for either puretone screening or tympanometry. Statistical tests for ear-effect were not significant.

Test Results by Sex

There was no significant difference between the puretone screening results for males and females. Based on 8,399 cases, 12.1 percent

of the males failed and 12.5 percent of the females failed. When considering the puretone test-retest reliability of those failing the initial screenings, again there were no significant differences between the performances of males and females. The lack of a sex difference for puretone testing was in contrast to the results obtained for tympanometry, where a slight effect by sex was observed.[1]

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[1]For a discussion on this subject see Pressure and Compliance by Sex under the section on tympanometry results.

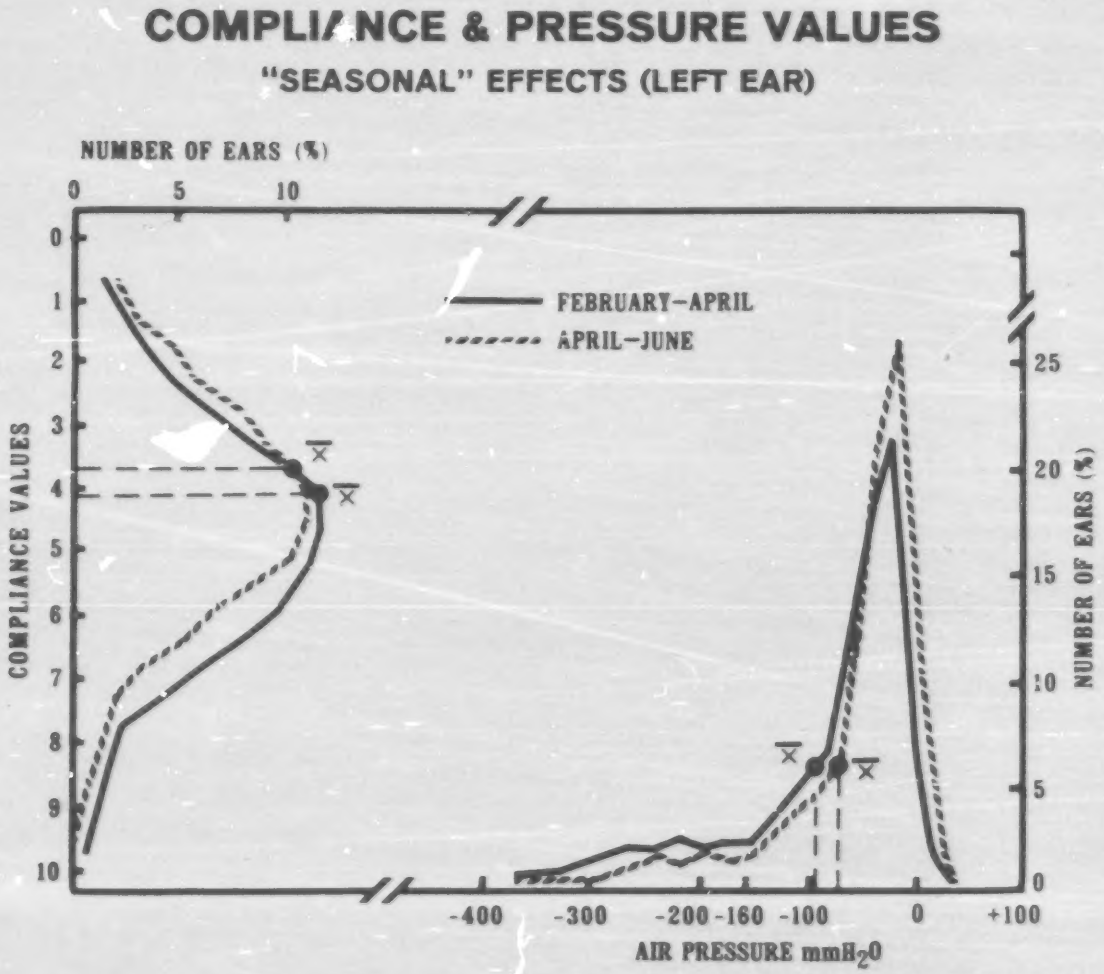
COMPLIANCE & PRESSURE VALUES
"SEASONAL" EFFECTS (LEFT EAR)
NUMBER OF EARS (%)
0 5 10
FEBRUARY–APRIL
APRIL–JUNE
COMPLIANCE VALUES
0 1 2 3 4 5 6 7 8 9 10
25 20 15 10 5 0
NUMBER OF EARS (%)
-400 -300 -200 -160 -100 0 +100
AIR PRESSURE mmH2O

FIGURE 4.4

Known Status of Hearing

Among the items of general information asked about each child was a question on the known status of hearing. With "Yes" (child has a known loss), "No," and "Unknown" for choices, the latter two categories were selected more often. Whether the selection resulted from factual knowledge, suspicion, impression, or expediency was beyond our control. Though admittedly an imprecise survey, we felt a comparison of the so-called known status with the obtained test results was justified for trend analysis.

Table 7.8 (Appendix I) summarizes the results of comparing the known status of each child's hearing with his/her performance by test. The categories of "No" (child has no loss) and "Unknown" are combined as "Unknown." As listed under the "Total Fail" column, 863 children failed puretone screening who were not known to have hearing problems. This number, which represents 89.8 percent of those failing puretone screening and 10.5 percent of the total screened, constitutes the new identifications resulting from the use of the ASHA puretone screening procedures. New identifications by tympanometry totaled 1493 (i.e., 94.8 percent of those failing tympanometry and 19.3 percent of the total screened). Since only one-in-ten of the puretone screening failures and one-in-twenty of the tympanometry screening failures were suspected of having problems, doubt is cast upon referral as a primary mechanism for identifying hearing-impaired children.

Having noted that test performance was grade-related, we extracted from Table 7.8 the percent who failed each test and whose hearing status was unknown prior to testing. The results, shown graphically in Figure 4.5, show a definite grade relationship. Regardless of why

a given child's hearing status was considered unknown, and even going so far as to challenge the validity of the entire decision process, it is alarming that the poorest estimates of hearing status were made for the youngest children. Not only is referral indefensible as the basis for the identification of children with hearing problems, but so also is the exclusion of the youngest children from an identification audiometry program.

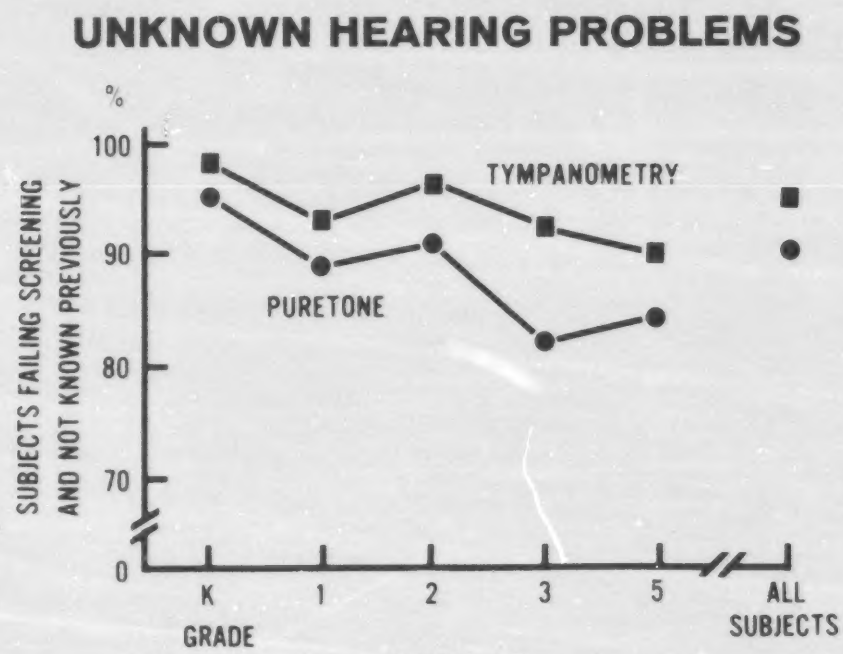

FIGURE 4.5

Test-Retest

Melnick, et al. (1964), evaluating a recommended identification audiometry scheme, found that 29 percent of those failing an initial puretone screening test passed a subsequent threshold test. Wilson and Walton (1974), in a similar study, found that 52 percent of the first-screen failures passed a subsequent rescreening. As outlined in the procedures section of this report, all first-screen failures were rescreened on the test(s) failed.

The reasons for puretone and tympanometry rescreening are basically different and bear upon the optimal time interval between initial and rescreening examinations. In puretone testing, rescreening is for reliability assessment, the necessity for which arises from the subjective nature of puretone audiometry. According to ASHA recommendations, rescreening should take place within seven calendar days and ideally on the same day as the initial testing. Because of the transient nature of most middle ear pathologies, justification for tympanometry rescreening stems mainly from a concern for validity. Inasmuch as tympanometry is an objective procedure and effective in monitoring middle-ear abnormalities, rescreening first-screen failures over an extended time period is the procedure of choice.

The reasons for some of the children failing an initial screening and subsequently passing a rescreen were (with respect to this project) somewhat test-specific. It was generally advised during the project that whenever the testers were unsure as to the precise status of the child's hearing on a given test they were to fail the child in order that a re-examination would be assured. This conservative approach was expected to magnify the number of false positives at first screening compared to what might be obtained if infinite time were available.

In puretone screening it may be presumed that many false positives occur as a result of the subjective nature of the test paradigm in which factors such as attention span, distractability, and environmental noise undoubtedly have influence. By contrast, rescreening for tympanometry failures is included to allow sufficient time for transient middle ear abnormalities to stabilize.

Since a maximum of only seven calendar days was possible between the initial screening and the rescreening examinations for both puretone and tympanometry testing, we questioned from the outset the value in performing a tympanometry rescreen so quickly. Unfortunately the basic design did not permit our extending the time period. Therefore, some of those whose tympanometry performance was recorded as having shifted from "fail" to "pass" were borderline cases who were failed initially as a conservative course of action. In evaluating the significance of initial-failure to rescreen performance, it is important to note that the screening criteria dictated that whenever a child failed a test in part, he failed it in total.

Figure 4.6 presents the reduction obtained in false-positive identifications resulting from rescreening. The combined value of 51.1 percent false-positive reduction for puretone audiometry is in close agreement with the results of Wilson and Walton (1974). As shown also, a 30 percent reduction in false-positive identifications was noted for tympanometry. For both tests the reduction in false-positive identifications seems clearly grade-related. In fact, there is a curious parallel course in the upper grades between the puretone and tympanometric results. It is unfortunate that the experimental design did not include higher grade levels in order to determine at what grade (age) the graphs plateau.

Since approximately one-half of the initial failures by puretone screening and one-third of the initial failures by tympanometry passed the rescreening evaluations, it is patently essential that rescreening be included in all identification audiometry programs.

REDUCTION OF FALSE POSITIVE IDENTIFICATIONS

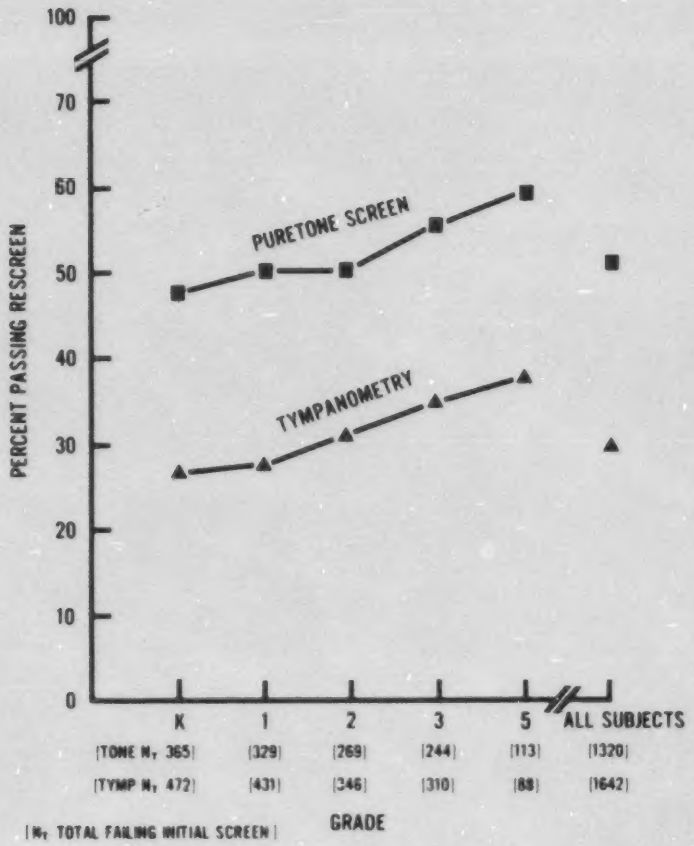

FIGURE 4.6

Ethnic Performance

Two of the towns had sufficient minority populations to permit limited comparative analyses between the Black, Puerto Rican, and White sub-groups (cf. Table 7.1, Appendix I). Because of the obvious impact of the season, it should be noted that testing was conducted in one of the two towns during early April and in the other town during early June.

Table 4.4 includes the pass/fail ratios for the three groups on the respective tests together with the obtained ratios for all subjects combined. Although no definitive trends emerged, both minority groups evidenced fewer tympanometry failures than the Whites, with the Blacks having approximately one-half as many.

PASS/FAIL RATIOS PER TEST AND MAJOR ETHNIC GROUP

		BLACK		PUERTO RICAN		WHITE		All Subjects	
		Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
Puretone Screen	N	1128	140	287	55	5578	766	7401	1039
	%	89.0	11.0	83.9	16.1	87.9	12.1	87.7	12.3
Tympan-ometry	N	1119	152	276	67	4596	1348	6336	1680
	%	88.0	12.0	80.5	19.5	77.3	22.7	79.0	21.0
Thres-hold	N	12	99	4	42	47	604	73	808
	%	10.8	89.2	8.7	91.3	7.2	92.8	8.3	91.7

TABLE 4.4

Test Performance vs. Absence

Seeking possible "at risk" predictors for hearing impairment, the number of absences accumulated during the school year to the date of initial testing was retained. Of the 8528 tested, 7676 children had one or more absences. The number of absences, divided by the sequential date within the school year (maximum = 180 days) yielded an absence quotient.

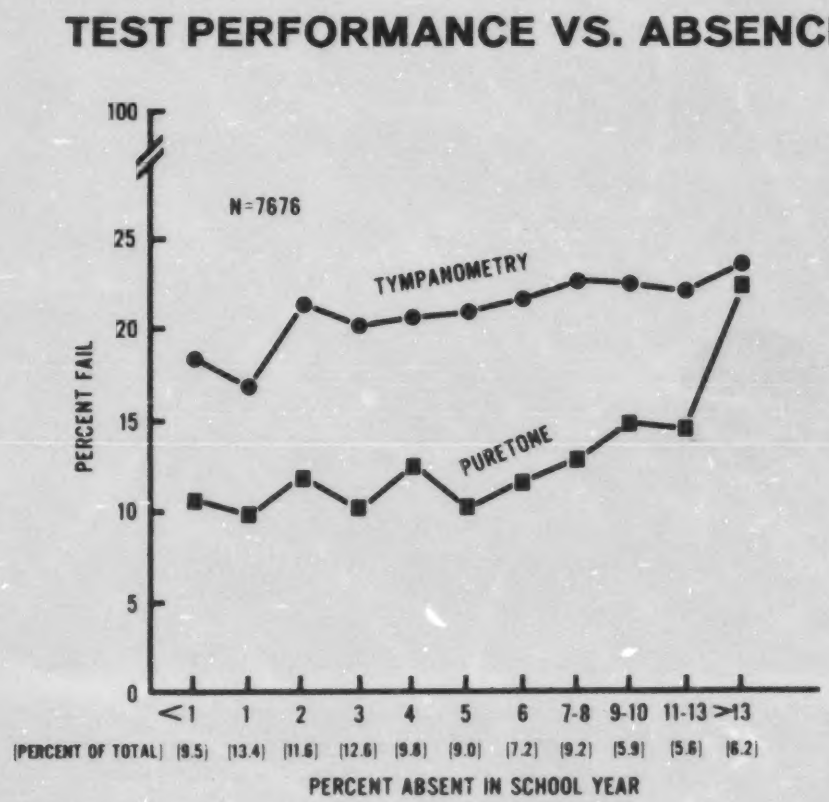

FIGURE 4.7

In Figure 4.7 these quotients (expressed in percent) for tympanometry and puretone screening failures are grouped in 11 sets ranging in size from 5.6 to 13.4 percent of the total reported. As shown, no definitive relationships are apparent, although there is some tendency in the higher absence groups for the percent of failures to increase with absence.

PURETONE TESTING

Screening Results by Frequency

Each child receiving a puretone screening test was tested at 1000, 2000, and 4000 Hz. Test performance by frequency and grade was examined by combining the results for the two ears and then computing the respective pass/fail ratios (Appendix I, Table 7.9). Figure 4.8 presents the percent failing each of the test frequencies as a function of grade level. Consistently more children failed at 1000 Hz than at any of the other frequencies, with failure at 4000 Hz being the second most common. Inasmuch as the ambient noise levels were

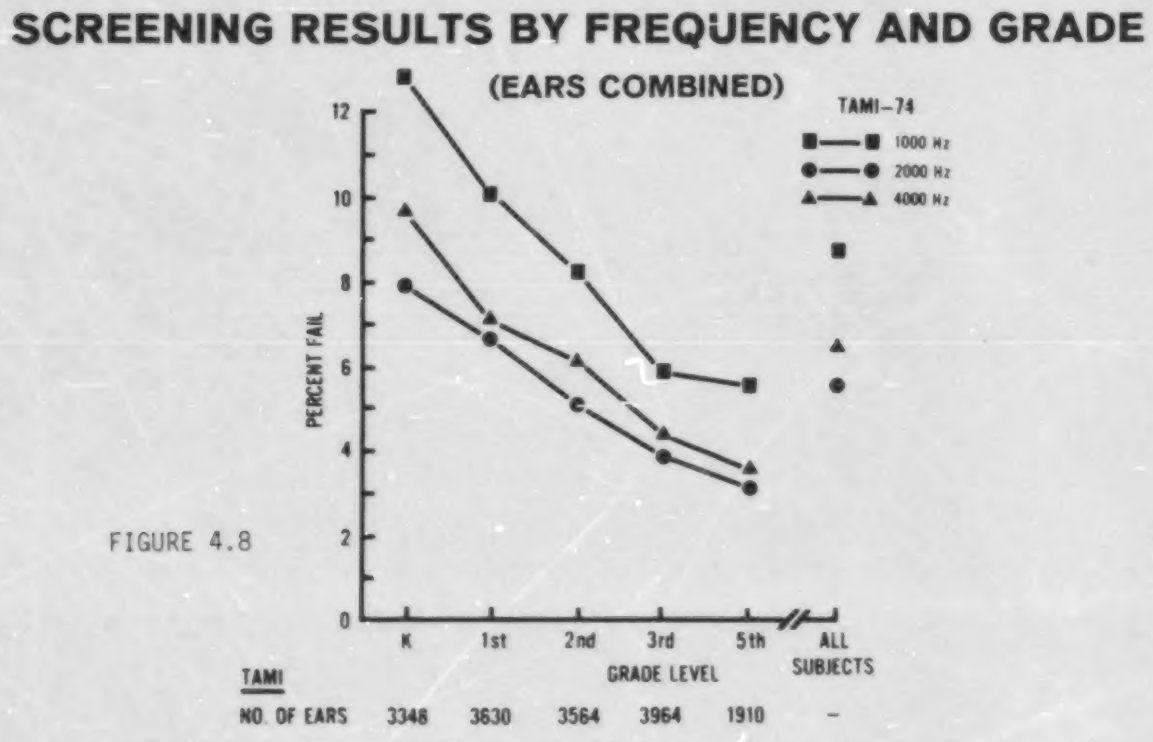

FIGURE 4.8

insufficient for masking at the screening frequencies (Appendix I, Table 7.5), it is possible that the failures at 1000 Hz were due primarily to conductive losses while the failures at 4000 Hz were due primarily to sensori-neural losses.

Threshold Results

The puretone average (PTA) hearing threshold loss was calculated for each ear and is represented by the average of the hearing threshold levels for 500, 1000, and 2000 Hz (referred to as the "speech frequencies"). As mentioned previously, threshold criteria were established relative to the child's total performance, not on his PTA alone. Thus, those with a PTA between zero and 20 dB do not represent the total number of children passing the threshold test because of high frequency (4000 Hz) losses.

Table 4.5 includes the performance by ear of the total threshold group. Essentially the same number had PTA's from zero to 20 dB as

THRESHOLD RESULTS

(A) Speech-Frequency Average	Left		Right	
	N	%	N	%
0 - 20 dB	394	47.5	405	48.8
21 - 40 dB	376	45.3	373	44.9
41 - 55 dB	54	6.5	44	5.3
56 - 70 dB	6	0.7	5	0.6
71 - 90 dB	0	0	3	0.4
	830	100.0	830	100.0

(B) Threshold Result	Left		Right	
	N	%	N	%
Pass	248	29.5	259	30.9
Fail	582	69.2	567	67.7
Inconclusive	6	0.7	8	1.0
Could Not Test	5	0.6	3	0.4
	841	100.0	837	100.0

TABLE 4.5

from 21 to 40dB, reflecting the number failed on the basis of a 15 to 20 dB average. As reported earlier, approximately one-in-ten of those failing a second puretone screening passed a threshold evaluation. As presented also in Table 4.5, approximately six percent of those receiving threshold tests had puretone averages in the 41 to 55 dB range with a few others having PTA's in the higher ranges. Approximately two-thirds of those tested in the left ear, and a like number in the right ear, were judged to fail the threshold evaluation.

TYMPANOMETRY

The mean, median, and modal pressure and compliance values obtained at the initial tympanometric screening are presented in Table 4.6. The values for middle ear pressure are somewhat lower than have heretofore been described as normative (cf. Brooks, 1968, 1973; McCandless and Thomas, 1974; Renvall, et al., 1973). For comparison, the distributions of the obtained compliance and pressure values for all subjects are displayed in Figure 4.9 and Appendix I (Tables 7.10-7.13). Means for the various curves are shown by dotted lines drawn perpendicularly to the respective axes.

PRESSURE-COMPLIANCE VALUES

All Subjects (Left Ear) (N - 7854)

	$\bar{x}$	Mdn	Mode
Air Pressure (mm H_2O)	-83	-46	-10
Compliance (Arbitrary Units)	3.9	3.9	4.0

TABLE 4.6

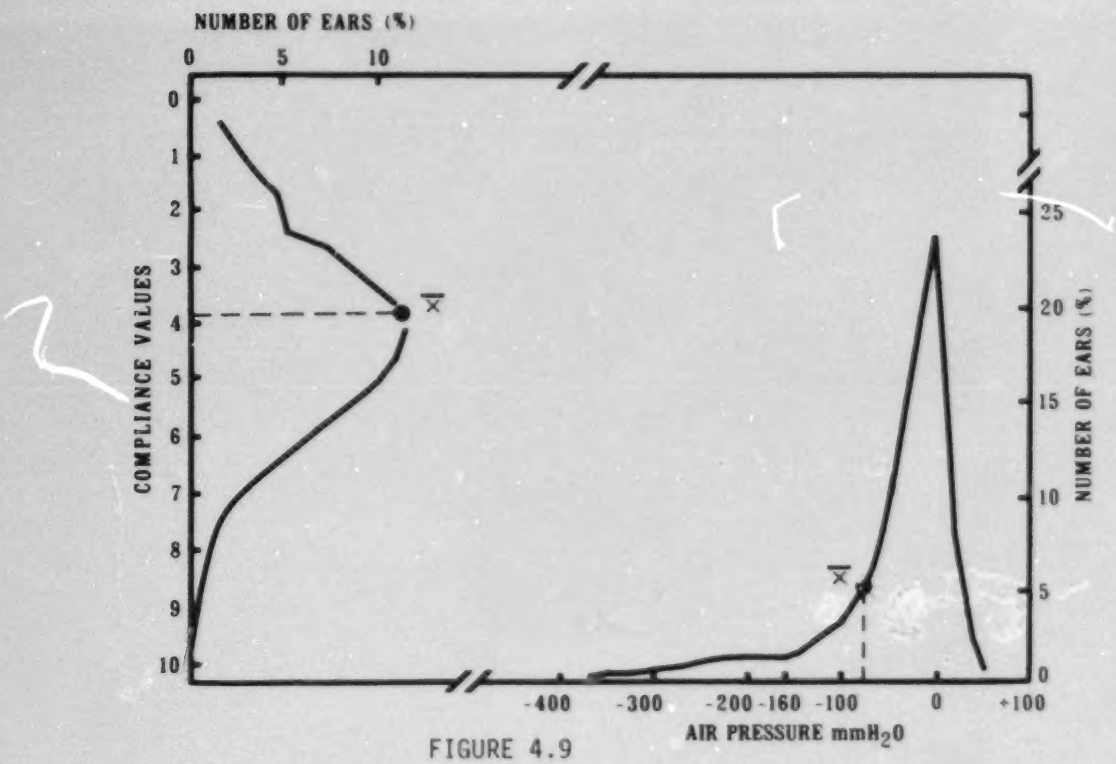
COMPLIANCE & PRESSURE VALUES
ALL SUBJECTS (LEFT EAR)
NUMBER OF EARS (%)
0 5 10
COMPLIANCE VALUES
0 1 2 3 4 5 6 7 8 9 10
25 20 15 10 5 0
NUMBER OF EARS (%)
-400 -300 -200 -160 -100 0 +100
AIR PRESSURE mmH2O

FIGURE 4.9

Analysis of the data for all subjects receiving the initial tympanometric screening disclosed that the pressure and compliance values within plus or minus one standard deviation of the respective means approximated the initial pass/fail criteria (Figure 4.10). For comparative purposes, compliance and pressure values within plus or minus two standard deviations are shown in the same figure.

Pressure and Compliance by Grade

Reportedly, young children exhibit more negative middle ear pressures than do older children and adults. Brooks (1969), in a study of 1053 four-through-eleven-year olds, found that reduced middle ear pressure was common in first-year school children, with middle ear pressure increasing with age. In Harker and Van Wagoner's study (1974)

of 710 Alaskan school children, 50 percent of the Kindergarten-through-third grade children displayed Jerger Type B or C tympanographs, with the greater prevalence among the lower grades. Normal atmospheric pressure is approximated around the age of 9 and above (Brooks, 1969; McCandless and Thomas, 1974). Data on compliance values are less definitive, but several investigators have reported that relative compliance increases with age (Brooks, 1971b; Jerger, 1970; Jerger, et al., 1972), a trend which would be expected when considering the reported age-related normalization of middle ear pressures concommitant with a decrease in the prevalence of Type B and C tympanograms.

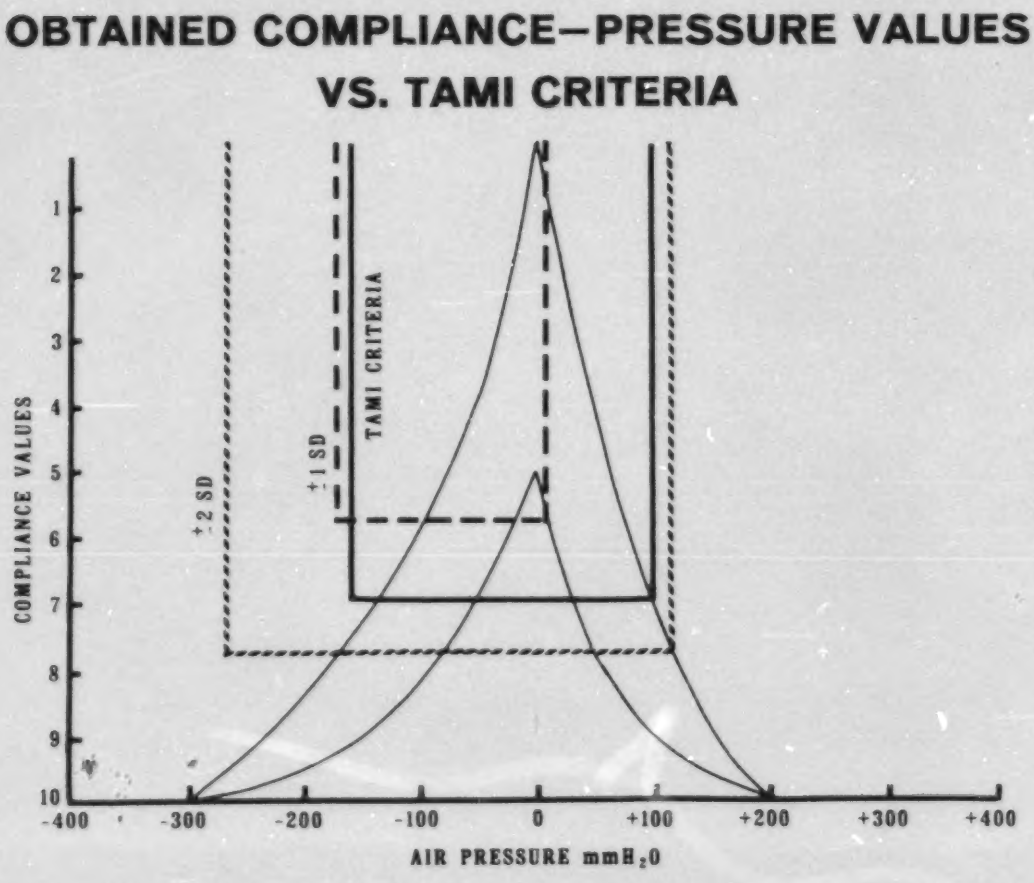

FIGURE 4.10

Data from this study show relatively stable compliance across grades. Mean values by grade are presented together with the variance in Figure 4.11, where the values are consistently between "4" and "5" on the compliance scale. The relative stability of the mean compliance value as a function of grade level, as well as the relative stability of the variance are clear from this figure (cf. Appendix I, Table 7.14).

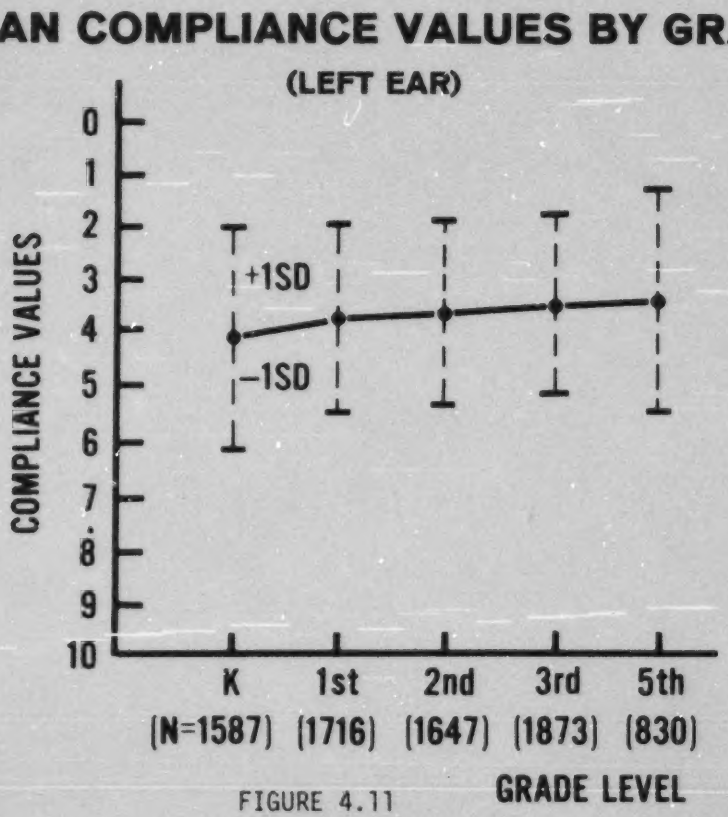

FIGURE 4.11

If -80 mm to 0 mm H_2O is taken as a strictly clinically-acceptable standard for normal middle ear pressure, the distribution of compliance values within this range was found to be virtually the same as for the entire sample. A total of 4649 left ears fell between these pressure values and for them the mean compliance value was 4.0 with remaining values distributed normally.

By contrast, mean middle ear pressures were progressively less negative with increased grade, and the variance around each mean diminished as a function of grade (Figure 4.12). Mean pressures ranged from -104 mm H_2O to -55 mm H_2O in grades Kindergarten through fifth, respectively. Brooks (1969, 1974), Harker and Van Wagoner (1974), Jerger (1970), and McCandless and Thomas (1974) have all reported similar trends. Figure 4.2 illustrates the importance of these trends in terms of the percentage of children failing the tympanometric screenings in the various elementary grades.

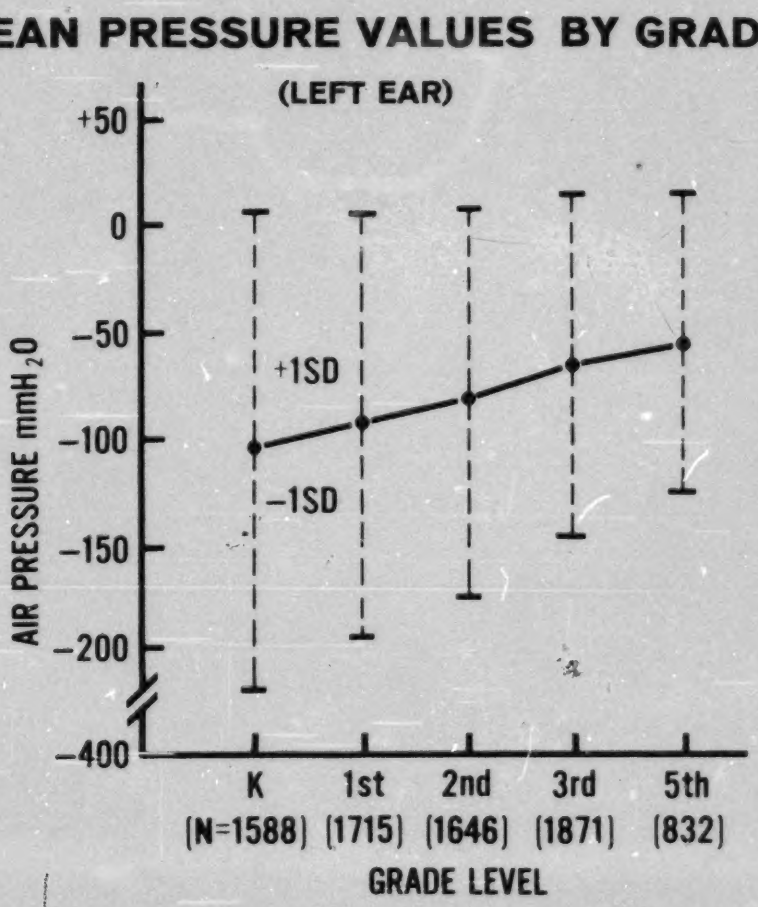

FIGURE 4.12

Pressure and Compliance by Sex

There is a suggestion in the literature (Jerger, et al., 1972; Zwislocki and Feldman, 1974; Bicknell and Morgan, 1968) that females show greater compliance values (i.e., less compliant middle ear systems) than males, and that this difference reaches its maximum at approximately age 30. Using static compliance measures, Jerger found a difference of about .1 cc between males and females in the 6-9 year age range. While our measures of compliance were not in absolute physical terms (cubic centimeters), we were able to compare indirectly our findings to those referenced. The difference found between males and females was negligible, but in the reported direction: the male mean equalled 3.8 and the female mean equalled 4.0.

The measured middle ear pressures presented a reversal in the means for boys and girls, where the girls presented somewhat greater (i.e., less negative) pressures than the boys. With 4005 boys and 3814 girls receiving an initial tympanometry screening, the girls' pressure was 6 mm greater than the boys' (boys, -86 mm H_2O; girls, -80 mm H_2O). These findings were in accord with the further observation that 16.7 percent of the boys and 14.8 percent of the girls fell below the -160 mm H_2O criterion level. Because of such slight differences in pressure and compliance values between the two groups, we find no argument for adjusting the pass/fail criteria between the sexes.

Shape Analysis

Tympanometric shapes were defined by four idealized categories, seen earlier in Figure 3.3. In order to examine the interrelationship of tympanographic shape and pass/fail results, we looked at the data in two ways: first, within a given shape category we detemmined the percentage failing tympanometry; and, secondly, of the total sample that failed, the distribution of shapes. The data are contained in Table 4.7.

The "peaked" category was observed in 92 percent of the cases, and 26.7 percent of these failed tympanometry (the "off-limits" and "peaked" categories were combined). "Rounded" tympanograms were obtained from only 4.1 percent of the cases, but over two-thirds of these (68.8 percent) were recorded as failures. "Flat" tympanograms occurred 3.9 percent of the time and all were failures. Based on these figures, one would predict that less than one-third of a similar school population would fail on the basis of negative pressure alone ("peaked" coincided with normal compliance in 94.4 percent of the cases, that is, greater than "7," N = 441). The degree of predictiveness increases from over two-thirds to 100 percent with "rounded" to "flat" configurations, respectively.

Looking at the dispersion of shapes within the group failing the initial tympanometric screening, we observed that of those failing, two-thirds had "peaked" tympanographs and the remaining one-third was divided between "flat" and "rounded" shapes. Slightly more were flat than were rounded. It is tempting to hypothesize that more than one-third of the failing ears had some serous fluid behind the tympanic membrane, but we had no otological verification.

TYMPANOGRAPHIC SHAPE ANALYSIS
(Left Ear)

Shape Prevalence vs. Tympanometry Performance

	SHAPE		
	Flat	Rounded	Peaked
Prevalence	3.9%	4.1%	92%
Number of Cases	303	320	7234
Tymp. Failure	100%	68.8%	26.7%

Tympanometric Shapes for Initial Test Failures

	SHAPE		
	Flat	Rounded	Peaked
Number of Cases	298	220	893
Prevalence	21.1%	15.6%	63.3%

TABLE 4.7

Screen-Rescreen Correlation

Liden, et al. (1970a), in a study of 163 ears found subject test-retest consistency on tympanometry to be clinically satisfactory. Brooks (1971a), in a similar study using 1053 children having olotogically normal middle ears, showed that test-retest results were satisfactory clinically when a series of nine tests per individual were conducted over an 18-month period. In a study of 40 neonates, Keith (1973) reported a correlation coefficient of .91 for right ears and .79 for left ears on tympanometry test-retest measurements.

To insure reliability throughout the course of the project, daily checks were made on each tymparometer and recorder using a staff member known to have a normal middle ear. Test-retest results per instrument and between instruments were found to be sufficiently stable that screen-rescreen correlations on pressure and compliance were justified.

Table 4.8 presents the screen-rescreen correlations for two separate populations: a group of 410 pupils from the first and second grades who passed when screened initially (Table 4.8-A), and a second group comprised of all initial screen failures who received a rescreen (Table 4.8-B). The time lapse between screenings was seven days for the first group and from one to seven days for the second group. All pupils in the first group were tested between May 15th and June 15th, while those in the second group were tested throughout the project.

All of the obtained correlation coefficients are significant at the 0.01 level of confidence, although differences in the amount of correlation within and between groups are evident. Highest correlations

INITIAL-TO-RESCREEN CORRELATION (A)

Initial Results = "Pass"; Time Lapse = 7 days; N = 410

		PRESSURE ($mm H_2O$)				COMPLIANCE (Arbitrary Units)			
Ear	Test	Mean	SD	Net Change ($\bar{x}$)	Corr.	Mean	SD	Net Change ($\bar{x}$)	Corr.
Left	Initial	-43.66	37.57	-9.51	0.400	3.43	1.65	+0.13	0.806
	Rescrn	-53.17	53.66			3.56	1.70		
Right	Initial	-48.05	39.02	-6.68	0.223	3.55	1.65	+0.16	0.751
	Rescrn	-54.73	50.79			3.71	1.72		

(B)

Initial Results = "Fail"; Time Lapse = 1-7 days; N = 1598

		PRESSURE ($mm H_2O$)				COMPLIANCE (Arbitrary Units)			
Ear	Test	Mean	SD	Net Change ($\bar{x}$)	Corr.	Mean	SD	Net Change ($\bar{x}$)	Corr.
Left	Initial	-194.70	119.64	+19.60	0.626	4.79	2.28	-0.13	0.705
	Rescrn	-175.10	120.71			4.66	2.23		
Right	Initial	-197.66	122.24	+23.74	0.547	4.85	2.27	-0.19	0.712
	Rescrn	-173.92	130.59			4.66	2.17		

TABLE 4.8

were obtained for compliance measures in the "normal" group and the lowest for pressure measures in the "normal" group.

Differences between the means for both pressure and compliance suggest that as a group the middle-ear status of the "normals" was becoming worse while the status of "abnormals" was improving. For those passing initially, there was a net change of -9.51 and -6.68 mm H_2O middle ear air pressure for the left and right ears respectively. Simultaneously, net compliance changes of +0.13 and +0.16 were recorded for the left and right.[1]

The magnitude of the compliance change for the "abnormals" was essentially the same as for the "normals," although in the opposite direction. Pressure changes for the "abnormals" were from two-to-three times as great as for the "normals." None of the observed differences between means is significant statistically, but suggest a trend which merits further examination. We concluded that air pressure measures are most representative of the dynamic state of the middle ear and therefore the best single index of current status.

---

[1]Based upon the American Electromedics scaling in use at the time of this study, middle ear compliance and the compliance value were inversely related.

BETWEEN-TEST ANALYSES

Puretone Screening - Tympanometry Agreement

Since our project was designed to identify children suffering not only from educationally significant hearing losses, but also from potentially educationally significant losses, we were interested in determining the number of children who displayed abnormal tympanometric patterns undetected by puretone screening. Melnick, et al. (1964), in an evaluation of a recommended program for identification audiometry (cf. Darley, 1961), reported that approximately one-half of the cases of active middle ear pathology were not detected through application of the recommendations. Harker and Van Wagoner (1974) reported abnormal impedance results in 10 percent of 710 Alaskan children who passed the puretone screening, while Bluestone, et al. (1973), in a study of 84 children, found middle ear effusions at myringotomy equally distributed above and below thresholds of 25 dB HTL.

For 7928 children who received both tympanometry and puretone screening tests, 74.3 percent passed both and 7.5 percent failed both. The sum of these two values, or the concordance, was 81.8 percent (Table 4.9), which is consistent with data reported by Randolph, et al. (1974). We found also that 13.3 percent of the children passed the puretone screening and failed the tympanometric, while 4.9 percent did just the opposite.

Puretone Threshold - Tympanometry Agreement

Table 4.10 illustrates the agreement between tympanometry and

PURETONE SCREENING-TO-TYMPANOMETRY CONCORDANCE

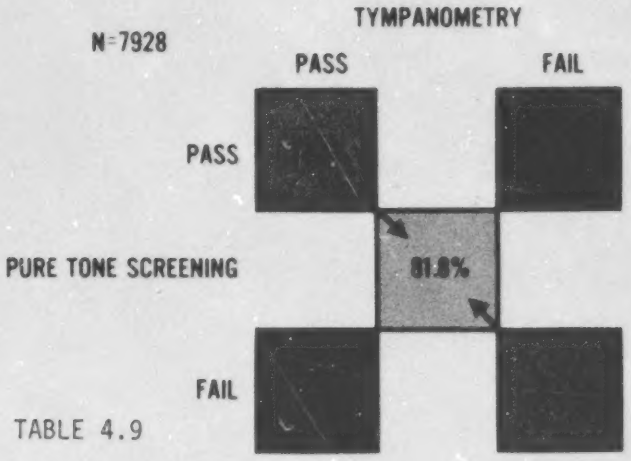

TABLE 4.9

puretone threshold test results. A total of 839 children received both tests, and, of these, 58.7 percent failed both while 4.5 percent passed both. An interesting figure of 32.5 percent failed the threshold test but passed tympanometry -- demonstrating the independence of the two tests and the need to perform both.

PURETONE THRESHOLD-TO-TYMPANOMETRY CONCORDANCE

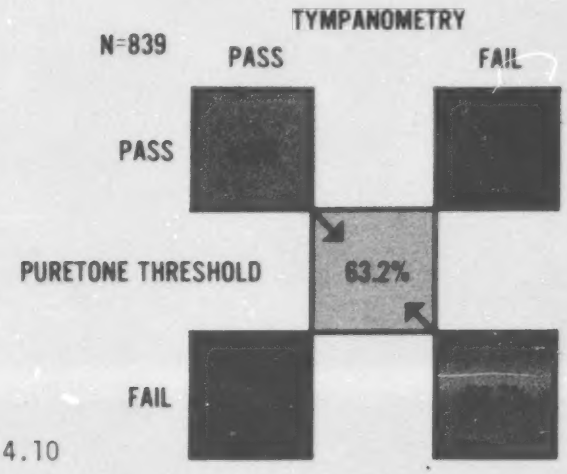

TABLE 4.10

REACTIONS

Following the completion of the project, each participating town was sent two types of questionnaires to survey opinion regarding the project and to determine the feasibility and practicality of continuing such an endeavor.

NURSE AND CLINICIAN REACTION

A questionnaire was distributed to the nurses and speech clinicians who participated in the project covering the participants' reactions to the project, responses received from other participants, and the willingness and feasibility of continuing the project in the future (Appendix III, Section 9.4). The questionnaire included responses dealing with skills gained in tympanometry and puretone procedures and the desire for future workshops on impedance.

Pre-Training Materials and Training Procedures

The majority of the nurses and speech and hearing clinicians reported that the supervisory meetings met specific needs related to respective roles in connection with executing the project. Pre-project instructions and fact sheets were found to be sufficient and helpful, and theoretical discussions concerning tympanometry and puretone testing were found to be adequate.

Testing Procedures

Responding to questions about puretone testing and procedures, 86 percent of the speech clinicians and nurses indicated a willingness

to use the ASHA model for puretone screening in the future. Sixty percent of the respondents felt that prior to the project they already possessed the skills necessary to conduct puretone screening and threshold testing. They also felt that they required much less supervision in puretone screening. Eighty-five percent of the speech clinicians desired more supervision in threshold testing procedures.

Although the nurses and speech clinicians stated that they still felt inadequate in several areas relating to tympanometric procedures, 86 percent reported that they had gained sufficient skills in tympanometry to use it in the future. All of the respondents stated that they now had a basic understanding of what tympanometry measures and that the tympanometric supervision by the TAMI central staff was adequate and beneficial.

Sixty-seven percent felt no need for on-going consultation and/or training in puretone procedures while 91 percent expressed a need for additional information and training in tympanometry. Eighty-six [illegible] expressed an interest in attending future impedance workshops. Areas of interest included the meaning and reading of tympanometric results, calibration, theory, advice on recommendations and referrals, and the acoustic reflex.

Project Continuation

Fifty-five percent of the respondents felt it was feasible for puretone testing to be completed within three days per school. Seventy percent of the nurses and speech clinicians did not know if their administration would support the use of tympanometry or invest in the

equipment in the future.

All of the nurses and speech clinicians indicated that the teachers were generally cooperative in preparing for Project TAMI and during the testing. All stated that the teacher response to the project was positive and that there was parental support for the use of tympanometry in their schools. Ninety-six percent of the parent volunteers had a favorable reaction to Project TAMI and 95 percent of the nurses and clinicians would use volunteers in the future. Eighty-two percent of the respondents expressed an interest in continuing the project.

In response to questions concerning the future use of tympanometry, 51 percent favored testing Kindergarten through third grades, as had been done in Project TAMI. The remaining 49 percent was divided among seven other possible grade combinations.

Referral and Follow-up

The average time lapse between the completion of testing and when the towns received the student listings was two and one-half weeks. For the majority of the towns, one to three weeks then elapsed before referral (if any) by the district. Eighty-seven percent of the respondents stated that they sent referrals to either an otologist or local pediatrician, and 92 percent stated that they planned to retest each child placed under medical care.

Joint Effort

Seventy-four percent of the nurses and speech clinicians felt

that the project had changed the working relationship between the nursing and clinician staffs for the better, and they credited the project with allowing more and better communication between the professions. The remaining 26 percent stated that the working relationship between the two staffs had always been good. Ninety-four percent of those surveyed would consider using a similar team approach in the future.

ADMINISTRATIVE REACTION

A questionnaire dealing with the administrators' responses to the project, the responses received from other participants, and the willingness and feasibility of continuing Project TAMI in the future was distributed to each participating school administrator, principal, and director of pupil personnel (Appendix III, Section 9.3).

Interest

Sixty percent of the administrators said that they were "greatly" interested in continuing to have tympanometry incorporated in the hearing screening program in their schools. Eighty-five percent believed that detection of abnormal middle ear conditions (as provided by tympanometry) should be incorporated routinely into the health services provided by the schools.

Given the size of the project and the time limitations under which it was administered, almost all of the administrators (96 percent) believed Project TAMI to be very efficient. Also, 85 percent stated that the project caused only limited disruption in the daily

routine of their schools. Ninety-six percent indicated that their schools had adequate advance notice of the project.

Practicability for the Future

Eighty-one percent of the administrators stated that it was either completely, or generally, feasible to complete a mass hearing-screening in their schools within two to four days. Questioned as to whether a very quiet room could be made available for up to three days in each school, 29 percent said that such space could be guaranteed and 43 percent said that it could possibly be found. Fourteen percent of the administrators surveyed stated that such a room was unavailable.

The majority of administrators, 75 percent, stated that they would encourage the town or Board of Education to invest in a tympanometer within the next three years.

In reference to the calibration of district audiometers, 48 percent said that their audiometers were calibrated yearly, and 15 percent stated every other year. However, 33 percent of the administrators did not know how often their audiometers were calibrated.

Staff and Parental Reaction

Eighty-five percent of the administrators stated that reactions received from teachers concerning Project TAMI had been positive. In this case, 15 percent had had no comments from their teachers. The comments received from the nurses and speech clinicians involved in the project were supportive 85 percent of the time. Also, 70 percent stated that supportive reactions had been received from parents in their district.

CONCLUSIONS

Beyond statistics on the numbers screened per minute, or the cost of testing each child, or the informational yield, practicability, per se, is inconsequential without acceptance. If "new tricks" will not be learned, or if "old tricks" are not modifiable, the "better mousetrap" will remain on the shelf. A thorough and systematic public relations campaign may be as essential in a feasibility study as the experimental design. Objectively, at least, we believe that the majority of the goals of the project were met and the practicability of the model was demonstrated.

GOAL REVIEW

Eight of the nine goals listed in Chapter 2 were met as stated. The fourth, and most critical, goal of having the model adopted in at least two of the participating towns was not achieved. Although the equipment was made available at nominal charge and procedures were developed for providing consultative services, none opted to continue the use of tympanometry. Explanations have included the lack of funds for any additional activities, overburdened (and often reduced) staffs, and a lack of administrative support.

UTILITY OF THE MODEL

Records were kept on the time required per child to complete both puretone and tympanometry screenings and on the number of children who could not be tested by tympanometry because of an inability to obtain

proper ear canal seals or because of a refusal to cooperate. Using volunteers for data recording and traffic management, as has been described, an average of 1.5 minutes was required for tympanometry and 1.0 minutes for puretone screening. As a measure of testability, we determined that only 74 out of over 8,000 children did not produce usable tympanographs for either ear at the initial screening, and only five of the 74 were never able to be tested (Table 6.1). Usable data were obtained for 99.94 percent of the cases, indicating the utility of tympanometry in elementary schools. By comparison, Harker and Van Wagoner (1974), in a study of 710 Alaskan school children, obtained satisfactory tympanometric results on all but 1.2 percent of the children seen.

TYMPANOMETRY TESTABILITY

Ear Canal Seals and Tympanographs:
(TOTAL CASES=8016)

EAR(S)	TEST DAY(S)	USABLE N	USABLE %	NOT USABLE N	NOT USABLE %
Either	I	7942	99.08	74	0.92
Left	I and II	8010	99.93	6	0.07
Right	I and II	8004	99.85	12	0.15
Either	I and II	8011	99.94	5	0.06

TABLE 6.1

SUGGESTED TYMPANOMETRY CRITERIA

If tympanometry is included in identification audiometry programs, selection of the pass/fail criteria to be employed must account for the availability of audiologists and otologists, the availability

of equipment and personnel to study abnormal middle ear conditions over time, and, particularly, local attitude regarding the target population to be identified. In order to determine compliance and pressure cut-off values that might be proposed for stand-alone field identification audiometry programs incorporating tympanometry, comparisons were made on a child-by-child basis between the tympanographic and the puretone screening results for the left ear. With this type of comparison, a tone-to-tymp concordance value of 82.9 percent was obtained (Figure 6.1). Further study of the data suggested that a stepped compliance-pressure criterion line might be used for the lower pressure values. The illustrated "pass-zone" steps from -160 mm equivalent water pressure to -200 and then to -240, but demands successively greater compliance. With the original criteria, total tympanometry failure for the left ear was 18 percent, while with the above suggested criteria tympanometry failure would be approximately 14 percent. Use of these values is justified only when the routine inclusion of an audiologist and an otologist on the identification team cannot be assured, and where local attitude regarding referrals for attention focuses on the child manifesting a loss in sensitivity for puretones.

CAUTIONS

If audiologic practitioners are readily available and if serial monitoring of tympanometric performance can be assured, it would be reasonable to place increased emphasis on tympanometry as the basis

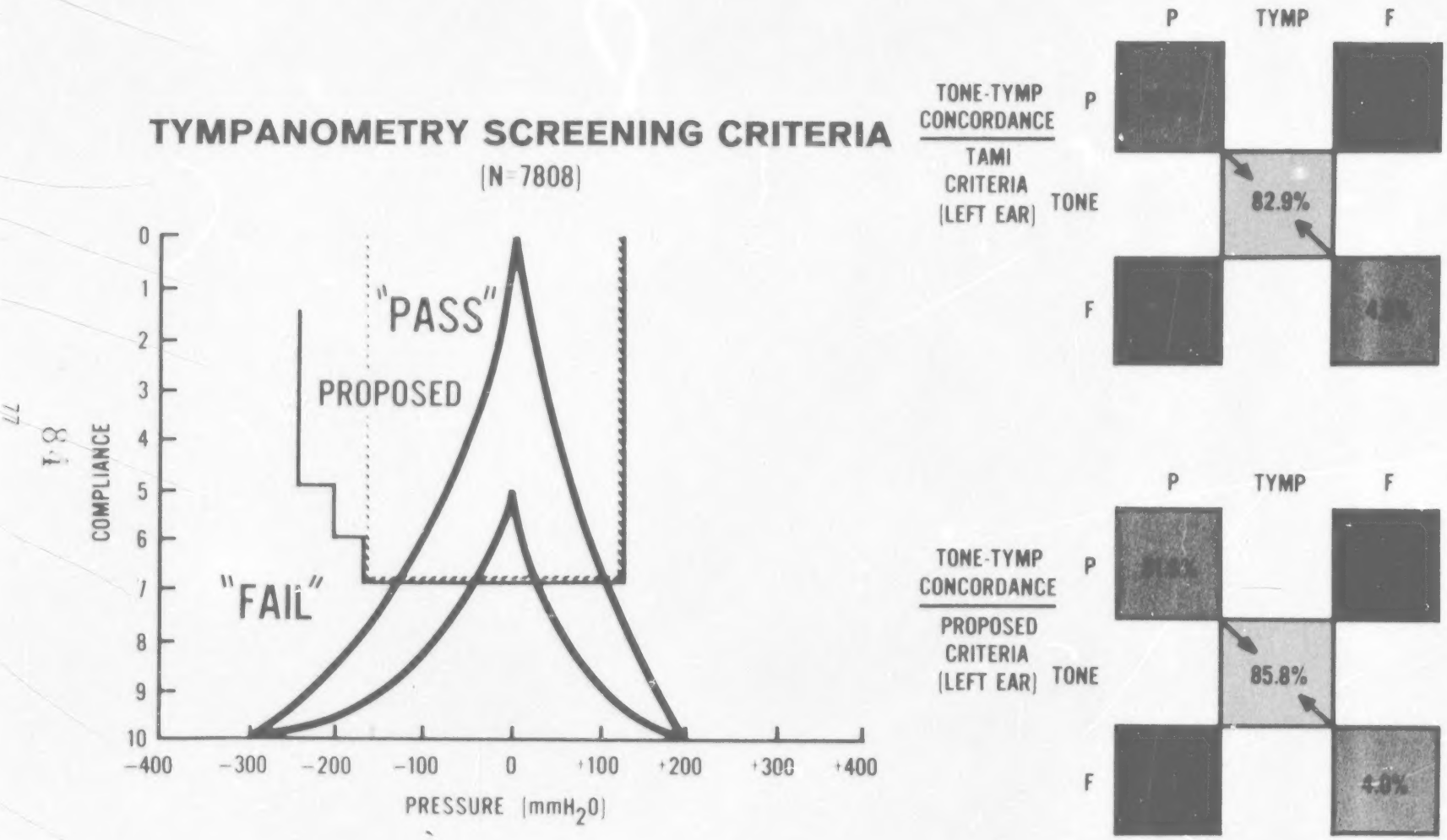
TYMPANOMETRY SCREENING CRITERIA
(N=7808)
"PASS"
PROPOSED
"FAIL"
COMPLIANCE
0
1
2
3
4
5
6
7
8
9
10
−400
−300
−200
−100
0
+100
+200
+300
+400
PRESSURE (mmH2O)
P
TYMP
F
TONE-TYMP CONCORDANCE
TAMI CRITERIA (LEFT EAR)
TONE
82.9%
P
TYMP
F
TONE-TYMP CONCORDANCE
PROPOSED CRITERIA (LEFT EAR)
TONE
85.8%

FIGURE 6.1

for referral and to make more stringent the pass criteria. Lacking such, over emphasis can lead only to the referral of large numbers of children with abnormal middle ear conditions which would very likely not be verified by otoscopy. Delays in referral and the transient nature of many of the middle ear problems of this age group make it probable that the condition would be either alleviated, or at least not obvious, by the time of medical examination. Lack of medical confirmation can be embarrassing. Such was our experience. Although we had every reason to believe that our criteria were thoroughly defensible, and that those failing should receive medical attention, when tympanometric failure was not accompanied by puretone failure the results were frequently rejected by the medical practitioner.

REFLECTIONS

Routine inclusion of tympanometry in hearing conservation programs for schools is not only practicable but desirable. Nursing and speech and hearing personnel can be taught quickly to operate the equipment and obtain reliable data. The slight additional time required for such testing is more than offset by the valuable information obtained on the status of the middle ear. Abnormal middle ear conditions should be detected and used as supportive evidence of the need for referral. The relative stability of the puretone screening results observed across the two seasons included in this study suggests that puretone results remain the basis for referral

from mass screening programs, and that tympanometric failure be monitored over time to establish whether the condition is chronic or transient. Care should be exercised in referring for medical attention those children having abnormal tympanograms who do not simultaneously present reduced sensitivity for puretones.

APPENDIX I

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GENERAL ANALYSIS - CONTINUED - 30 JANUARY 1975 - RUN NO 1 01/30/75 PAGE 5

FILE TAMI (CREATION DATE = 06/26/74) COMPLETE FILE - PROJECT TAMI - SPRING 1974

* CROSSTABULATION OF *

VAR012 ETHNIC GROUP BY VAR001 SCHOOL DISTRICT

* PAGE 1 OF 1

		VAR001 TOWN						
VAR012	COUNT / ROW PCT / COL PCT / TOT PCT	1	2	3	4	5	6	ROW TOTAL
		172.00	492.00	642.00	1015.00	1031.00	1552.00	
1.00 NATIVE AMER		1	0	37	1	4	0	43
		2.3	0.0	86.0	2.3	9.3	0.0	0.5
		0.1	0.0	2.6	0.1	0.4	0.0	
		0.0	0.0	0.4	0.0	0.0	0.0	
2.00 BLACK		66	32	829	47	257	49	1280
		5.2	2.5	64.8	3.7	20.1	3.8	15.3
		3.7	2.2	58.2	3.4	23.0	4.0	
		0.8	0.4	9.9	0.6	3.1	0.6	
3.00 MEX AMER		0	1	0	0	0	4	5
		0.0	20.0	0.0	0.0	0.0	80.0	0.1
		0.0	0.1	0.0	0.0	0.0	0.3	
		0.0	0.0	0.0	0.0	0.0	0.0	
4.00 ORIENTAL		1	1	1	4	8	8	23
		4.3	4.3	4.3	17.4	34.8	34.8	0.3
		0.1	0.1	0.1	0.3	0.7	0.7	
		0.0	0.0	0.0	0.0	0.1	0.1	
5.00 PUERTO RICAN		22	30	158	7	122	6	345
		6.4	8.7	45.8	2.0	35.4	1.7	4.1
		1.2	2.1	11.1	0.5	10.9	0.5	
		0.3	0.4	1.9	0.1	1.5	0.1	
6.00 WHITE		1600	1342	322	1331	672	1132	6399
		25.0	21.0	5.0	20.8	10.5	17.7	76.6
		90.2	94.0	22.6	95.2	60.1	93.6	
		19.2	16.1	3.9	15.9	8.0	13.6	
7.00 OTHER		83	22	77	8	56	11	257
		32.3	8.6	30.0	3.1	21.8	4.3	3.1
		4.7	1.5	5.4	0.6	5.0	0.9	
		1.0	0.3	0.9	0.1	0.7	0.1	
COLUMN TOTAL		1773	1428	1424	1398	1119	1210	8352
		21.2	17.1	17.0	16.7	13.4	14.5	100.0

NUMBER OF MISSING OBSERVATIONS = 176

TABLE 7.1

PURETONE SCREENING SUBJECTS

	School District							
	1	2	3	4	5	6	Total	%
Pre-K	0	67	15	3	19	0	104	1.23
K	355	284	282	282	259	238	1700	20.14
1	403	306	312	354	254	213	1842	21.82
2	368	305	325	343	232	217	1790	21.21
3	335	345	339	403	308	263	1993	23.61
4	6	6	3	0	1	4	20	0.24
5	342	179	146	0	0	290	957	11.34
6	2	1	0	0	0	1	4	0.05
Grade Unknown	0	2	1	13	13	1	30	0.36
Totals	1811	1495	1423	1398	1086	1227	8440	100
%	21.46	17.71	16.86	16.56	12.87	14.54	100	

TABLE 7.2

TYMPANOMETRY SCREENING SUBJECTS

	School District							
	1	2	3	4	5	6	Total	%
Pre-K	0	67	15	3	35	0	120	1.50
K	284	284	282	283	252	241	1626	20.28
1	300	308	315	356	250	213	1742	21.73
2	249	303	326	343	233	217	1671	20.85
3	250	346	342	406	307	263	1914	23.88
4	6	6	3	6	2	4	27	0.34
5	233	179	146	1	1	290	850	10.60
6	2	1	1	0	0	1	5	0.06
Grade Unknown	0	2	3	13	42	1	61	0.76
Totals	1324	1496	1433	1411	1122	1230	8016	
%	16.52	18.66	17.88	17.60	14.00	15.34		100

TABLE 7.3

PURETONE THRESHOLD SUBJECTS

	School District							
	1	2	3	4	5	6	Total	%
Pre-K	0	18	2	0	4	0	24	2.72
K	51	43	35	42	27	40	238	27.02
1	57	27	43	47	34	23	231	26.22
2	40	25	36	28	18	24	171	19.41
3	26	25	26	27	21	15	140	15.89
4	0	3	1	0	0	0	4	0.45
5	16	11	12	0	0	11	50	5.68
6	1	1	0	0	0	0	2	0.23
Grade Unknown	0	0	1	5	14	1	21	2.38
Totals	191	153	156	149	118	114	881	100
%	21.68	17.37	17.71	16.91	13.39	12.94	100	

TABLE 7.4

AMBIENT NOISE LEVELS -- PURETONE AUDIOMETRY

District/ School	Room	No. of Measures	Median Measurement During Test Lin.	dBC	dBA	500 Hz
1-01	Gym Stage w̄ Curtain	5	75	65	47	no filter
1-02	Auditorium	6	69	58	55	no filter
1-03	Gym Stage w̄ Curtain	8	60	58	49	48
1-04	Gym Stage w̄ Curtain	3	62	55	48	no filter
1-05	(Data missing)	-	--	--	--	--
1-06	Teacher's Room	3	64	46	48	37
2-01	Music Room w̄ Carpet	3	67	58	43	39
2-02	Music Room w̄ Carpet	3	67	55	47	37
2-03	Music Room w̄/o Carpet	3	68	50	47	45
2-04	Band Room	2	70	64	55	49
2-05	Speech Room	3	68	61	45	45
2-06	Resource Room	4	64	56	42	37
3-01	(Data missing)	-	--	--	--	--
3-02	Gym Office	2	73	58	45	33
3-03	Library w̄ Carpet	3	75	65	45	34
3-04	Gym	3	75	64	51	36
3-05	Auditorium Office	2	66	58	48	37
4-01	Auditorium Stage	2	69	55	48	43
4-02	Auditorium	5	65	55	43	42
4-03	Storage Room	3	65	53	45	38
4-04	(Data missing)	-	--	--	--	--
4-05	Classroom	2	60	56	45	35
5-01	Library w̄ Carpet	3	68	57	45	35
5-02	Resource Room	2	63	40	39	35
5-03	Resource Room	3	65	57	48	40
5-04	(Data missing)	-	--	--	--	--
5-05	Library w̄/o Carpet	3	69	54	34	30
6-01	Speech Room	7	63	44	44	37
6-02	Speech Room	6	66	55	44	40
6-03	Classroom #173	5	64	58	48	44
6-04	Nurse's Room w̄ Carpet	3	66	56	44	42
6-05	Gym Stage w̄ separating panel and curtain	3	68	56	35	33

TABLE 7.5

PURETONE SCREENING RESULTS

Grade		TOWN 1 N	TOWN 1 % Per Grade	TOWN 2 N	TOWN 2 % Per Grade	TOWN 3 N	TOWN 3 % Per Grade	TOWN 4 N	TOWN 4 % Per Grade	TOWN 5 N	TOWN 5 % Per Grade	TOWN 6 N	TOWN 6 % Per Grade	TOTAL N	TOTAL % Per Grade
Pre-K	P+	0	0	43	64.2	12	80.0	0	*	14	73.7	0	0	69	66.3
	F	0	0	24	35.8	3	20.0	3	*	5	26.3	0	0	35	33.7
K	P	294	82.8	234	82.4	234	83.0	230	81.6	226	87.3	190	79.8	1408	82.8
	F	61	17.2	50	17.6	48	17.0	52	18.4	33	12.7	48	20.2	292	17.2
1	P	332	82.4	279	91.2	262	84.0	302	85.3	216	85..	187	87.8	1578	85.7
	F	71	17.6	27	8.8	50	16.0	52	14.7	38	15.0	26	12.2	264	14.3
2	P	326	88.6	281	92.1	283	87.1	310	90.4	211	90.9	188	86.6	1599	89.3
	F	42	11.4	24	7.9	42	12.9	33	9.6	21	9.1	29	13.4	191	10.7
3	P	304	90.7	317	91.9	301	88.8	372	92.3	285	92.5	246	93.5	1825	91.6
	F	31	9.3	28	8.1	38	11.2	31	7.7	23	7.5	17	6.5	168	8.4
4	*	6	*	6	*	3	*	0	0	1	*	4	*	20	*
5	P	319	93.3	166	92.7	132	90.4	0	0	0	0	277	95.5	894	93.4
	F	23	6.7	13	7.3	14	9.6	0	0	0	0	13	4.5	63	6.6
6	*	2	*	1	*	0	0	0	0	0	0	1	*	4	*
Gr. Unk	*	0	0	2	*	1	*	13	*	13	*	1	*	30	*
TOTAL	P	1575	87.4	1320	88.8	1224	86.3	1214	87.7	952	88.8	1088	89.1	7373	87.9
	F	228	12.6	166	11.2	195	13.7	171	12.3	120	11.2	133	10.9	1013	12.1
	*	8		9		4		13		14		6		54	
GRAND TOTAL		1811		1495		1423		1398		1086		1227		8440	

*Group size insufficient for comparison.
+P=Pass; F=Fail.

TABLE 7.6

TYMPANOMETRY SCREENING RESULTS

Grade		TOWN 1 N	TOWN 1 % Per Grade	TOWN 2 N	TOWN 2 % Per Grade	TOWN 3 N	TOWN 3 % Per Grade	TOWN 4 N	TOWN 4 % Per Grade	TOWN 5 N	TOWN 5 % Per Grade	TOWN 6 N	TOWN 6 % Per Grade	TOTAL N	TOTAL % Per Grade
Pre-K	P+	0	0	39	58.2	11	73.3	1	*	18	51.4	0	0	69	57.5
	F	0	0	28	41.8	4	26.7	2	*	17	48.6	0	0	51	42.5
K	P	189	66.6	210	73.9	220	78.0	199	70.3	198	78.6	155	64.3	1171	72.0
	F	95	33.4	74	26.1	62	22.0	84	29.7	54	21.4	86	35.7	455	28.0
1	P	207	69.0	236	76.6	272	86.3	254	71.3	191	76.4	151	70.9	1311	75.3
	F	93	31.0	72	23.4	43	13.7	102	28.7	59	23.6	62	29.1	431	24.7
2	P	180	72.3	246	81.2	286	87.7	269	78.4	199	85.4	160	73.7	1340	80.2
	F	69	27.7	57	18.8	40	12.3	74	21.6	34	14.6	57	26.3	331	19.8
3	P	192	76.8	301	87.0	301	88.0	349	86.0	281	91.5	205	77.9	1629	85.1
	F	58	23.2	45	13.0	41	12.0	57	14.0	26	8.5	58	22.1	285	14.9
4	*	6	*	6	*	3	*	6	*	2	*	4	*	27	*
5	P	207	88.8	170	95.0	129	88.4	1	*	0	*	249	85.9	756	88.9
	F	26	11.2	9	5.0	17	11.6	0	*	1	*	41	14.1	94	11.1
6	*	2	*	1	*	1	*	0	0	0	0	1	*	5	*
Gr. Unk	*	0	0	2	*	3	*	13	*	42	*	1	*	61	*
TOTAL	P	975	74.1	1202	80.8	1219	85.5	1073	77.1	887	82.3	920	75.2	6276	79.2
	F	341	25.9	285	19.2	207	14.5	319	22.9	191	17.7	304	24.8	1647	20.8
	*	8		9		7		19		44		6		93	
GRAND TOTAL		1324		1496		1433		1411		1122		1230		8016	

*Group size insufficient for comparison.
+P=Pass; F=Fail.

TABLE 7.7

KNOWN LOSSES PER GRADE AND TEST

N Row % Col % Tot %	Hearing Loss	K Pass	K Fail	1 Pass	1 Fail	2 Pass	2 Fail	3 Pass	3 Fail	5 Pass	5 Fail	TOTAL Pass	TOTAL Fail
Puretone Screen	KNOWN	18 52.6 1.3 1.1	14 43.8 4.9 0.8	39 58.2 2.5 2.2	28 41.8 10.8 1.5	33 66.0 2.1 1.9	17 34 9.0 0.9	36 55.4 2.0 1.8	29 44.6 17.7 1.5	8 44.4 0.9 0.8	10 55.6 15.9 1.1	134 57.8 1.8 1.6	98 42.2 10.2 1.2
	UNKNOWN	1381 83.5 98.7 82.0	272 16.5 95.1 16.1	1514 86.8 97.5 83.6	231 13.2 89.2 12.7	1558 90.1 97.9 87.5	172 9.9 91.0 9.7	1780 93.0 98.0 89.9	135 7.0 82.3 6.8	877 94.3 99.1 92.5	53 5.7 84.1 5.6	7110 89.2 98.2 86.7	863 10.8 89.8 10.5
Tympanometry Screen	KNOWN	18 66.7 1.6 1.1	9 33.3 2.0 0.6	38 57.6 2.9 2.2	28 42.4 6.6 1.6	37 72.5 2.8 2.2	14 27.5 4.2 0.9	49 69.0 3.0 2.6	22 31.0 7.8 1.2	11 55.0 1.5 1.3	9 45.0 9.8 1.0	153 65.1 2.5 2.0	82 34.9 5.2 1.1
	UNKNOWN	1143 72.2 98.4 70.9	441 27.8 98.0 27.4	1203 76.1 97.1 73.2	394 23.9 93.4 23.0	1296 80.4 97.2 77.9	316 19.6 95.8 19.0	1571 85.8 97.0 82.6	259 14.2 92.2 13.6	738 89.9 98.5 87.8	83 10.1 90.2 9.9	6001 80.1 97.5 77.6	1493 19.9 94.8 19.3
Threshold Test	KNOWN	0 0 0 0	13 100.0 5.9 5.6	1 40 4.0 0.5	24 96.0 11.9 10.6	0 0 0 0	16 100.0 10.2 9.5	1 4.2 16.7 0.7	23 95.8 17.4 16.7	1 14.3 20.0 2.0	6 85.7 13.3 12.0	3 3.5 4.8 0.4	82 95.6 10.9 10.0
	UNKNOWN	14 6.4 100.0 6.0	206 93.6 94.1 88.4	24 11.9 96.0 10.6	177 88.1 88.1 78.3	12 7.8 100.0 7.1	141 92.2 89.8 83.4	5 4.4 83.3 3.6	109 95.6 82.6 79.0	4 9.3 80.0 8.0	39 90.7 86.7 73.0	59 8.1 95.2 7.2	672 91.9 89.1 82.4

Cases with missing data are excluded.

*All percentages are based on the counts per major cell (e.g., "K" or "Total")

TABLE 7.8

INITIAL SCREENING RESULTS BY FREQUENCY AND GRADE

(Ears Combined)

		K		1		2		3		5		All Subjects	
		Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
1000 Hz	N	2920	427	3263	365	3274	291	3729	232	1804	106	15,192	1460
	%	87.2	12.8	89.9	10.1	91.8	8.2	94.1	5.9	94.5	5.5	91.2	8.8
2000 Hz	N	3082	265	3392	238	3386	179	3810	151	1850	60	15,732	921
	%	92.1	7.9	93.4	6.6	95.0	5.0	96.2	3.8	96.9	3.1	94.5	5.5
4000 Hz	N	3025	322	3376	253	3348	217	3785	175	1846	64	15,592	1059
	%	90.4	9.6	93.0	7.0	93.9	6.1	95.6	4.4	96.6	3.4	93.6	6.4

TABLE 7.9

FILE TAMI (CREATION DATE = 06/26/74) COMPLETE FILE - PROJECT TAMI - SPRING 1974

VARIABLE VA4041 TYMPAN COMPLIANCE LEFT EAR - FIRST REC

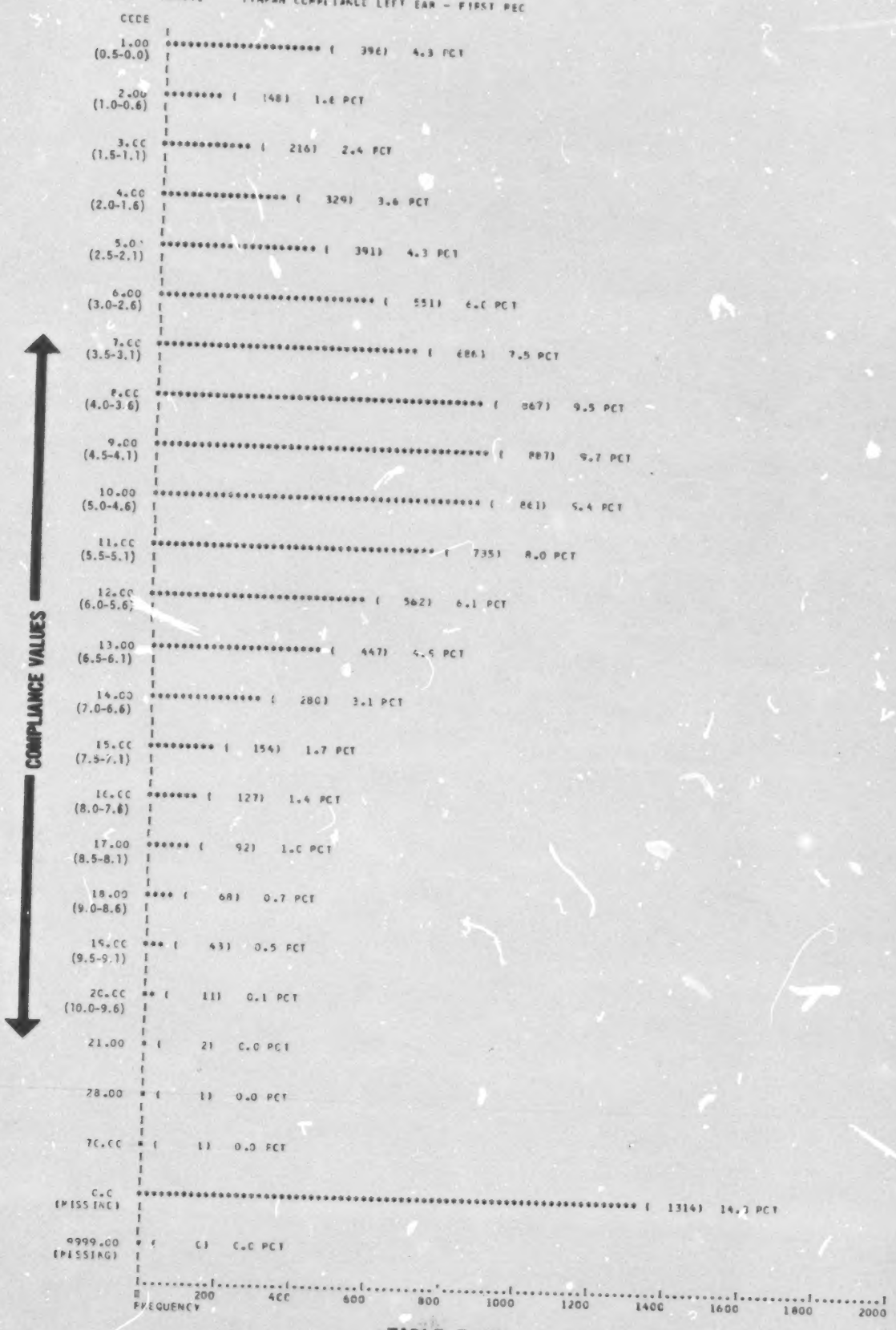


TABLE 7.10

FILE TAMI (CREATION DATE = 06/26/74) COMPLETE FILE - PROJECT TAMI - SPRING 1974

VARIABLE V8R041 TYMPAN COMPLIANCE LEFT EAR - FIRST REC

VALUE LABEL	Compliance Range (Arbitrary units)	VALUE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
	(0.5 - 0.0)	1.00	396	4.3	5.0	5.0
	(1.0 - 0.6)	2.00	148	1.6	1.9	6.9
	(1.5 - 1.1)	3.00	216	2.4	2.7	9.7
	(2.0 - 1.6)	4.00	329	3.6	4.2	13.9
	(2.5 - 2.1)	5.00	391	4.3	5.0	18.8
	(3.0 - 2.6)	6.00	551	6.0	7.0	25.9
	(3.5 - 3.1)	7.00	686	7.5	8.7	34.6
	(4.0 - 3.6)	8.00	867	9.5	11.0	45.6
	(4.5 - 4.1)	9.00	887	9.7	11.3	56.9
	(5.0 - 4.6)	10.00	861	9.4	11.0	67.9
	(5.5 - 5.1)	11.00	735	8.0	9.4	77.2
	(6.0 - 5.6)	12.00	562	6.1	7.2	84.4
	(6.5 - 6.1)	13.00	447	4.9	5.7	90.1
	(7.0 - 6.6)	14.00	283	3.1	3.6	93.6
	(7.5 - 7.1)	15.00	154	1.7	2.0	95.6
	(8.0 - 7.6)	16.00	127	1.4	1.6	97.2
	(8.5 - 8.1)	17.00	92	1.0	1.2	98.4
	(9.0 - 8.6)	18.00	68	0.7	0.9	99.3
	(9.5 - 9.1)	19.00	43	0.5	0.5	99.8
	(10.0 - 9.6)	20.00	11	0.1	0.1	99.9
		21.00	2	0.0	0.0	100.0
		26.00	1	0.0	0.0	100.0
		70.00	1	0.0	0.0	100.0
		0.0	1314	14.3	MISSING	100.0
		9999.00	0	0.0	MISSING	100.0
		TOTAL	9169	100.0	100.0	100.0

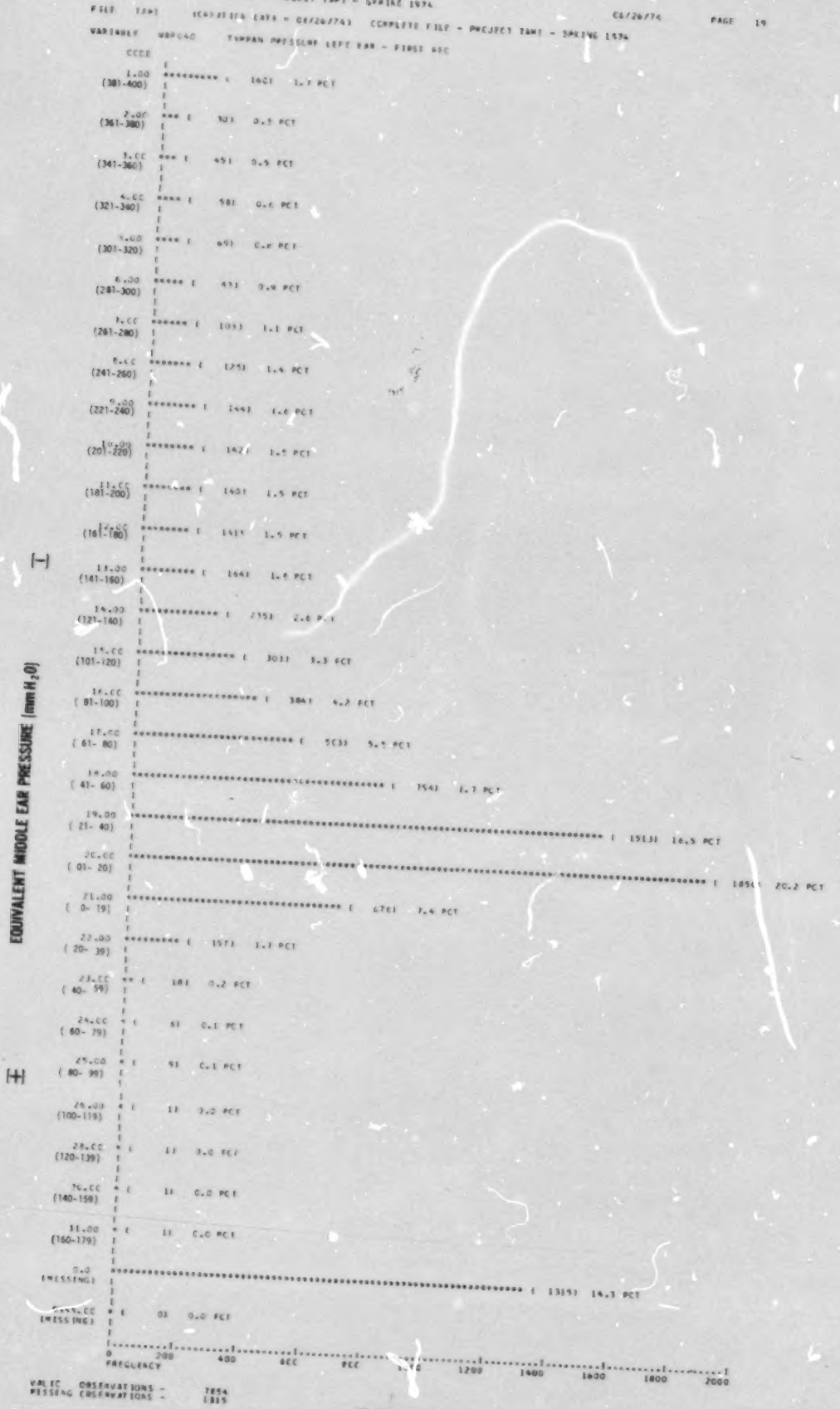
STATISTICS..

MEAN	8.799	(3.8995)	STD ERROR	0.044	MEDIAN	8.887	(3.9435)
MODE	9.000		STD DEV	3.897	(1.9485)	VARIANCE	15.187
KURTOSIS	7.526		SKEWNESS	0.513	RANGE	69.000	
MINIMUM	1.000	(0)	MAXIMUM	70.000			

VALID OBSERVATIONS - 7855
MISSING OBSERVATIONS - 1314

TABLE 7.11

VARIABLE VARC40 TYMPAN PRESSURE LEFT EAR - FIRST ASC



VALID OBSERVATIONS - 7854
MISSING OBSERVATIONS - 1315

TABLE 7.12

FILE TAMI (CREATION DATE = 06/26/74) COMPLETE FILE - PROJECT TAMI - SPRING 1974

VARIABLE YAR040 TYMPAN PRESSURE LEFT EAR - FIRST REC

VALUE LABEL		VALUE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
	Air Pressure Range (mm H_2O)					
	(381-400)	1.00	160	1.7	2.0	2.0
	(361-380)	2.00	30	0.3	0.4	2.4
	(341-360)	3.00	45	0.5	0.6	3.0
	(321-340)	4.00	59	0.6	0.7	3.7
	(301-320)	5.00	69	0.8	0.9	4.6
	(281-300)	6.00	85	0.9	1.1	5.7
	(261-280)	7.00	103	1.1	1.3	7.0
	(241-260)	8.00	125	1.4	1.6	8.6
[-]	(221-240)	9.00	144	1.6	1.8	10.4
	(201-220)	10.00	142	1.5	1.8	12.2
	(181-200)	11.00	140	1.5	1.8	14.0
	(161-180)	12.00	141	1.5	1.8	15.8
	(141-160)	13.00	164	1.8	2.1	17.9
	(121-140)	14.00	235	2.6	3.0	20.9
	(101-120)	15.00	301	3.3	3.8	24.7
	(81-100)	16.00	384	4.2	4.9	29.6
	(61- 80)	17.00	503	5.5	6.4	36.0
	(41- 60)	18.00	794	8.7	10.1	46.1
	(21- 40)	19.00	1513	16.5	19.3	65.4
	(01- 20)	20.00	1850	20.2	23.6	88.9
	(0- 19)	21.00	676	7.4	8.6	97.5
	(20- 39)	22.00	157	1.7	2.0	99.5
	(40- 59)	23.00	19	0.2	0.2	99.8
	(60- 79)	24.00	6	0.1	0.1	99.8
	(80- 99)	25.00	9	0.1	0.1	99.9
[+]	(100-119)	26.00	1	0.0	0.0	100.0
	(120-139)	28.00	1	0.0	0.0	100.0
	(140-159)	30.00	1	0.0	0.0	100.0
	(160-179)	31.00	1	0.0	0.0	100.0
	(180-199)	0.0	1315	14.3	MISSING	100.0
		9999.00	0	0.0	MISSING	100.0
		TOTAL	9169	100.0	100.0	100.0

STATISTICS..

MEAN	16.847	(-83.06)	STD ERROR	0.054	(1.08)	MEDIAN	18.702 (-45.96)
MODE	20.000		STD DEV	4.760	(95.2)	VARIANCE	22.659
KURTOSIS	2.180		SKEWNESS	-1.649		RANGE	30.000 (600)
MINIMUM	1.000	(-400)	MAXIMUM	31.000	(200)		

VALID OBSERVATIONS - 7854
MISSING OBSERVATIONS - 1315

TABLE 7.13

PRESSURE-COMPLIANCE VALUES BY GRADE

(Left Ear)

Grade	Pressure (mm H_2O)					Compliance (Arbitrary units)			
	N	Mean	Mdn	Mode	SD	Mean	Mdn	Mode	SD
K	1588	-104	-60	-10	109	4.2	4.3	4.5	1.9
1	1715	-97	-58	-10	99	4.0	4.0	4.0	1.9
2	1646	-79	-46	-10	91	3.8	3.9	4.0	1.9
3	1871	-67	-40	-10	83	3.7	3.8	4.0	1.9
5	832	-55	-34	-10	71	3.6	3.7	4.5	2.1
All Subjects	7854	-83	-46	-10	96	3.9	3.9	4.0	1.9

TABLE 7.14

APPENDIX II

CONTENTS

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GUIDELINES FOR THE SELECTION OF HEARING SCREENING FACILITIES

I. Room Size

A. Puretone:
1. For initial test days, a room approximately 45' x 60' is suggested in order to accommodate 4 stations simultaneously.
2. For rescreen day, a room of 45' x 60' will again be required.
3. Room suggestions: (a) Library
(b) Stage separated by panels and/or curtain
(c) Large classroom

B. Tympanometry:
1. For initial test days, a room approximately 45' x 60' is suggested in order to accommodate 3 stations simultaneously.
2. For rescreen day, a room of 45' x 60' will again be required if 3 stations will be operated. If there will be less than 3 stations, a room of 9' x 15' is necessary for maximum efficiency.
3. Room suggestions: (a) Multi-purpose room
(b) Gymnasium
(c) Auditorium
(d) Large classroom

II. Location of Room

A. Puretone: Testing should be accomplished in areas as free of excessive noise as possible. Consideration should, thus, be given to testing away from the boiler room, play area, kitchen, lunch room, and any other heavily trafficked area.

B. Tympanometry: Noise is not a factor in tympanometric testing. For efficient traffic management, however, the tympanometry facility should be as close to the puretone facility as possible. For efficient eartip sterilization, a nearby water source is desirable.

III. Internal Room Requirements

A. Puretone
1. Enough outlets for four pieces of equipment
2. Adequate lighting
3. Furniture
a. 4 3' x 6' tables, each with two chairs; or 4 pairs of desks and chairs
b. 1 3' x 6' table for data record retrieval and miscellaneous data recording

B. Tympanometry
1. Enough outlets for five pieces of equipment
2. Adequate lighting
3. Furniture
a. 3 3' x 6' tables, each with three chairs
b. 2 3' x 6' tables, each with two chairs

Note: The rooms should be as free of extraneous furniture as possible for adequate traffic management.

PURETONE SCREENING PROCEDURE

Situate the child so he cannot see any dials or hand movements. Be careful not to give visual or verbal cues, such as nodding your head, or asking if he has heard the tone as you present it, or moving your hands and arms excessively.

1. Using appropriate language, instruct the child to:

   a. raise his hand whenever he hears a tone, even if he barely hears it.
   b. keep his hand raised until the tone goes off.
   c. lower his hand as soon as the tone stops.

2. Place the earphones on the child and set the audiometer so that:

   a. the intensity dial is set at 40 dB HL.
   b. the frequency dial is set at 1000 Hz.
   c. the stimulus lever is in the "tone off" position.
   d. the signal is directed to the last ear tested on the previous child.

3. Depress stimulus lever for approximately 2-3 seconds. If the child does not respond, present the tone again. Reinstruct if no response.

4. Once the child is responding satisfactorily, reduce intensity to 20 dB. Present tone for 2-3 seconds. If child does not respond, up to three presentations are permissible before failing.

5. Change frequency dial to 2000 Hz; repeat as for #4.

6. Change frequency dial to 4000 Hz, intensity dial to 25 dB; repeat as for #4.

7. Tell aide "Pass" if all frequencies are passed. Indicate which frequencies are failed, if any. Avoid telling the child.

8. Switch signals to the opposite ear.

9. Test at 4000, 2000, and 1000 Hz.

NOTE: Failure to respond to any frequency in either ear constitutes failure of the original screening, and necessitates a re-screening.

Failure to respond to any frequency in either ear on the rescreening, results in immediate threshold testing of the failed ear(s).

PROCEDURES FOR IDENTIFICATION (SCREENING) AUDIOMETRY

The purpose of identification audiometry is to define those children who may have an educationally significant hearing loss, meaning a shift in air-conduction hearing sensitivity. The children so defined, are candidates for threshold audiometry. Identification audiometry does not attempt to indicate the amount of loss nor does it indicate, necessarily, the breadth of the loss in terms of number of frequencies involved. The sole purpose of an identification audiometry program is to define those children in need of further audiometric testing.

Many different procedures have been used in the past to screen groups of children. Before puretone audiometers were widely available, phonograph recordings were used. Probably the best known example of that type of testing was the Western Electric Fading-Numbers Test. Pairs of numbers recorded at progressively lower levels were delivered through as many as 40 headsets. The primary defect in the fading-numbers test was that children with hearing deficits in the range above 500 Hz could often pass the test. Other screening tests that employ highly familiar speech signals have the same difficulty.

As the availability of the puretone audiometer increased, puretone screening tests became more widely used. Both group tests and individual tests were developed. Group testing offers an apparent saving in time; however, this saving is usually not realized, being offset by the increased set-up time. In addition, calibration and maintenance of the multiple earphones and the difficulty in providing an adequate test environment for a large group of children are also problems, unless a mobile test unit is available. In situations where the tester must move from school to school and set up his equipment in each school, the individual sweep-frequency test, administered with a puretone audiometer is the test of choice. The procedures detailed in this presentation describe a method for accomplishing such a test.

Factors affecting test methodology

Before describing the specific test procedure, we should look first at several facts related to the choice of a test methodology. First, most identification audiometry programs must take place in a regular school environment. Sound-isolated test areas are not available in each school in most districts. Therefore, any consideration of procedure must recognize the fact that ambient noise may well be a problem during the test session. Second, ambient noise has its predominant energy in the low frequencies. Therefore, its effect on a screening test would be most pronounced for the low frequencies. The result of high ambient noise coupled with a screening test which included measurement in the low frequencies, will be a high number of over referrals (false-positive identifications). Nor is the phenomena limited to screening tests. Many investigators have done threshold measurements in the same environment in which the screening test was

accomplished and attempted to validate their screening results by showing large numbers of children with hearing loss in the low frequencies only. However, in carefully controlled studies in which the threshold validation measurements are completed in a sound-isolated room, it becomes apparent that there are not nearly so many children with hearing loss in the low frequencies only; in fact, ambient noise has simply affected threshold and screening tests in such a way as to suggest this problem.

The significance of this argument is to recognize that although it might be most efficient to screen a representative sample of frequencies including low- and high-frequency tones, the fact that ambient noise will affect the tests in the low frequencies precludes such a recommendation. Thus, the procedure described in this presentation may properly be considered a limited-frequency test, since the low frequencies are excluded. A recent research study, testing the accuracy of this method, demonstrated it to be very nearly as accurate as a screening test including the low frequencies and done in a sound-isolated test environment.

Screening procedures

Now, let us look at the specific method. The test frequencies of 1000 Hz, 2000 Hz, and 4000 Hz are included. Each ear is screened independently.

The screening levels are 20dB HL at 1000 Hz and 2000 Hz and 25 dB HL at 4000 Hz. In practice, the tester should screen at 20 dB HL at all frequencies, but if 4000 Hz is not heard, the audiometer output should be increased to 25 dB HL to determine pass or fail. Since most children will hear all tones at 20 dB HL, the hearing-level dial often remains at one setting for the entire test.

Failure criterion is defined as failure to respond at the recommended screening level at any frequency in either ear. All children failing the screening test are to be rescreened, preferably during the same day. We cannot over emphasize the importance of this mandatory rescreen. Recent research has shown that the rescreen will reduce by 50 percent the children who are referred for further testing, since many times the rescreen allows a child to complete the test satisfactorily rather than to be referred for threshold testing.

Children who fail the rescreen, meaning that they have failed two screening tests, shall be referred for threshold audiometric evaluation. Referral for medical treatment and/or educational management shall be based on the results of the threshold test. This system demands that threshold testing be accomplished without undue time passing between the screening testing and the threshold testing.

To review the specific procedure, we note first that the frequencies to be screened are 1000, 2000, and 4000 Hz in each ear. Second, that the screening levels are 20 dB HL at 1000 and 2000 Hz

and 25 dB HL at 4000 Hz. Finally, failure to respond at any frequency in either ear constitutes failure of the original screening test which results in a recommendation for a rescreen. Failure of the rescreen, based on the same criterion, constitutes basis for referral for threshold testing. Recommendations for both medical and non-medical help are to be based on the results of the threshold testing.

Procedural considerations

Next, we should look at procedural considerations related to the screening test. As in puretone threshold audiometry, certain general factors may influence the screening results. They are: (1) the instructions, (2) the response task, and (3) the manner in which the tester interprets the individual's response behavior during the test.

Instructions. Taken in order, we will consider the instructions first. They should be phrased in language appropriate to the child and should: (1) indicate he is to respond whenever the tone is heard even if barely heard; (2) indicate the method of response to be used; (3) indicate the need to signal as soon as the tone comes on and to continue to signal until the tone goes off; and (4) describe the method of indicating the ear in which the signal is heard.

In screening audiometry, the children are usually instructed in a group. The instructions will necessarily differ in wording depending on whether the children are Kindergarten age or high-school age. However, the basic principles enumerated above should be covered in any instructions regardless of age. An example of instructions for Kindergarten age children, which meet the requirements above, might be as follows: "You are going to hear a soft sound which is kind of like a whistle. No matter how soft it is, I would like you to raise your hand when you hear it and put your hand down when it goes away. Let's practice that now." At this point, the examiner may either whistle audibly or turn the tone on with the hearing level dial set at maximum output while holding the earphones in front of the children. Both the examiner and children are to raise their hand when the tone comes on and put them down when it goes away. If a child is hesitant to respond, the examiner may take his hand and show him the response using adequate social reinforcement such as a smile, or saying that's a good job, etc.

Once the children have shown that they can signal properly, the instructions might continue "Gee, that's great -- now I'm going to make the game harder since you're all doing so well. Let's say that if you hear the whistle in this ear you will point to it and if you hear it in this ear you will point to it. Now remember, raise your hand even if it is a very soft or tiny sound."

Those instructions may be contrasted to an example of the instructions one might use with an older group of children: "You are going to hear some very soft tones. I would like you to raise your hand as soon as you hear a tone, keep it up as long as you hear the tone, and put it down when the tone goes away. Please use your right hand for your right ear, and your left hand for your left ear. Remember, even if a tone is very soft, raise your hand when you hear it, keep it up as long as you hear it, and put it down when it goes away." In each set of instructions, the four factors listed have been included, even though the language used has been different. Remember, the important thing is to phrase the instructions in language comfortable to your manner of speaking and appropriate to the age of the child.

Response task. The second general area considered is that of response task. Some form of overt response is required from the subject to signal when the tone goes on and when the tone goes off. Any response task meeting this criterion is acceptable. Examples of commonly used responses include: (1) raising and lowering the finger, hand, or arm; and (2) pressing and releasing a signal-light switch. Children of school age may be expected to accomplish any of these tasks. Occasionally, a Kindergarten child or pre-school child may be fearful in a test situation and it may be advantageous to substitute a play-audiometry response task to overcome his fears. In such a case, the placement of a ring on a spindle or the dropping of a marble in a bottle, or similar activities may substitute as a response. However, when such a response is used, remember that the child is responding only to tone onset. Since the tester gets only one indication of response per signal, more sampling may be needed at each hearing level.

Response behavior. The third general area is that of interpretation of response behavior. The primary factors which the tester uses are: (1) latency of response, (2) presence of both on and off responses, and (3) the number of false alarm responses.

The latency of the on responses should be consistent. That is, the child should signal the tone onset without a long delay preceding his response.

Since each tone presentation provides the opportunity for two responses--on response and off response--the tester should take advantage of both in determining the validity of a child's response. The tester should remember that in determining whether or not a response is valid, the ability of the child to signal both onset and offset greatly facilitates the decision. If a child is simply raising

his hand any time while the tone is on and putting it back down immediately, there is a much better chance of his randomly responding and hitting some portion of the tone-on interval, when in fact he doesn't hear the tone at all. Thus, if a child is not signaling both tone on and tone off, the tester should remove the earphones and re-instruct the child.

Finally, false-alarm responses make it very difficult for the tester. A false-alarm response is defined as a response by the child when no tone is present. The tester should remember that the child may well think that he is pleasing the tester when he raises his hand, in fact, almost any child left for some time with no tone on following instructions, will raise his hand, imaginging that he does hear a tone. Some children are so eager to try to please, that they present a very high rate of false-alarm responses. When this occurs, the tester should first reinstruct the child saying, "Remember, I want you to raise your hand when you are sure (emphasize the sure) that you hear the tone." Along with the re-instruction the tester may want to present a tone at a clearly audible level and demonstrate to the child again the raising of his hand, keeping it up as long as the tone is on, and putting it down when it goes away, and then return to the screening level.

Possible problems in screening audiometry

Equipment calibration. The condition and calibration of your test equipment is, of course, crucial to the obtaining of valid results. Research has demonstrated that many portable audiometers in use in public school hearing conservation programs do not meet calibration standards. On the other hand, a recent study has demonstrated that if such equipment is placed in full calibration, it maintains good stability during periods of heavy use in screening audiometry, suggesting the fact that many audiometers used in schools may never have been placed in full calibration. The tester must determine that the equipment being used is receiving the necessary full-scale calibration on at least an annual basis. In addition to this, many school districts may want to provide the necessary sound-measurement equipment to complete intensity-only calibrations on a more frequent basis. Finally, each piece of equipment should be checked by the tester prior to the start of the day's testing. To complete such a check, the audiometer is to be plugged in and allowed to warm up at least five minutes. The tester then puts the earphones on himself, turns the hearing level dial to the screening levels and listens to the signal first in one ear and then in the other. This check allows the tester to be sure that equal signals are being delivered to each earphone. If not, he should use a spare audiometer. In addition, he listens for any audible clicks or other sounds which might clue the child as to the presence of the tone. If such clicks, etc., are present, again, a spare audiometer should be used. A reserve complement of 15-20 percent is suggested (or one spare for every six audiometers in use).

Test environment. The test environment must be adequately quiet to allow testing to be completed. A check to determine the adequacy of a test environment may be completed by using a sound level meter and comparing results to normative values. If such equipment is not available, you may presume that screening cannot be satisfactorily completed in any room where you cannot consistently hear all screening frequency tones at levels 10 dB less intense (softer) than the screening levels. In such cases, other testing space should be sought.

Earphone placement. The placement of earphones is important. The tester should place the earphones on the child and see that they are properly aligned with the ear canals. Occasionally a child, in placing the earphones, will not provide such an alignment and may even, in rare cases, fold the pinna over the ear in pulling the phones on from behind.

Unintentional cues. The mannerisms of the tester may provide unintentional cues to the child as to when the tone is on and when it is off. For example, if you look down at the test equipment, switch the frequency dial setting, look up at the child, and then turn the tone on, he may be responding only to the fact that you have looked at him expectantly. More subtle cues such as shoulder movement, etc., may be apparent to the child. Some testers have the child face away to avoid this problem. However, the tester then loses many valuable cues to responses in the form of eye movement, etc. Also, without eye contact, some social reinforcements such as a smile or a nod of the head cannot be used.

A good way to check for the possibility of unintentional cues is to have a friend serve as a subject and observe carefully your testing manner to see if any detectable cues are present. Similar to observable visual cues, timing cues may also be apparent. Testers often fall into a rhythmic pattern of tone presentation. The child may be responding to an expected tone based on the past rhythm of presentations rather than to an actual tone. Again, falling into a rhythmic pattern may produce a higher rate of false alarms. Vary the interval between tone presentations and see that you don't fall into a rhythmic pattern.

Response behavior. This may lead to a question of the number of signals to be presented at each frequency. Since in screening audiometry, fewer presentations are provided at each level, it becomes essential that the child realize that he is to raise his hand when the tone is on and put it down when the tone goes off. The child may believe that the simple act of raising his hand is what will please the tester. In your instructions to the children, you should emphasize that only if the hand is raised at the appropriate time, kept up for the duration of the tone, and put down at the end of the tone, is the task

being completed successfully. One good way of illustrating this is to use an audible whistle to teach the children to respond, and use a very pronounced effort to produce the whistle. Then, after several correct responses to your whistle by the group of children, go through the same elaborate physical motions without the whistle. Invariably, some children will raise their hand; you may then say something such as "Caught you, didn't we. Remember, your hand goes up only when the sound is there." Given the proper mental set, the child is prepared to indicate both an on response to tone onset and off response to tone offset. If the tester is satisfied that the child has responded to the tone, it may be necessary to provide only one presentation at each frequency. However, if any question exists in the tester's mind, multiple tone presentations should be used at each level. In such a case, it becomes crucial to vary the duration between tone presentations and, perhaps, even switch from one ear to the other, to determine that the child is in fact responding appropriately. If, after one or more of these methods has been attempted, the responses still seem somewhat questionable, the child should be failed on the screening test. Remember, each child is then rescreened and there will be an opportunity to re-instruct, and again sample the child's responses.

Misrecording of data. The recording of results is important. Misrecording of data may include two types of errors. First is the simple error in data recording on the Results Form. Be sure that you have entered the screen result for the proper frequency and ear. The second type of error may be the intentional misrecording of data such as occurs because of previous expectations. For example, we may expect a child to have better hearing than he is demonstrating and so accept any response which happens to fall during the time the tone was on rather than holding to the rather rigorous response criteria described above. We then record him as a pass. The tester's first reaction to this type of information is "Who, me?," yet I would dare say that all persons who test hearing have at one time or another misrecorded data in this manner.

Audiometer cues. Just as the tester may provide unintentional cues to the child, the operation of the audiometer may provide unwanted cues. For example, a noisy tone interrupter switch or the overzealous pushing of a tone interrupter switch may provide a clearly audible click which the child detects. The child is not intentionally trying to cheat on the screening test; however, when he hears this click, he is apt to imagine the tone is present and so signal. Other examples of instrument cues include the reflection of a tone-on light on the face plate of the audiometer from a shiny button on the tester's clothing, the visibility of this tone light from the back of the audiometer so that the child can clearly see the tone-on light going on and off, or the presence of acoustic clicks coupled with the signal, as discussed under calibration. Again, careful observation is necessary to find and/or avoid this problem.

Fear of test situations. Some children, particularly very young children, may be frightened by the circumstances surrounding the test. In most such cases, simple reinstruction and/or inclusion of play-audiometry response procedures will allow the tester to complete the test. Reinstruction is an important part of the rescreening process, also. Children frequently fail the first screen because they did not understand the instructions.

Grade level. Practical experience along with research findings have suggested that the highest degree of inaccuracy in identification audiometry is found in first grade children, contrary to what might be expected. It is quite possible that the tester spends the necessary time to teach the Kindergarten child the correct responses, and then presumes that the first grader will recall the test procedure when he is tested the following year. Apparently, such is not the case. The tester should be aware that first graders may need the same extensive instructions and, perhaps, practice given to Kindergarten children.

To conclude, the completion of identification audiometry demands first that proper equipment, maintained and calibrated, be provided. Secondly, an adequate test environment must be available. Third, the child must be properly instructed. Fourth, a standard method of measurement is to be employed. Finally, the tester must avoid any unintentional cues which would influence the test results and critically evaluate the response behavior.

PURETONE AIR-CONDUCTION THRESHOLD AUDIOMETRY

Puretone threshold audiometry is defined as the measurement of an individual's hearing sensitivity for calibrated pure tones. Two general methods are employed clinically: (1) testing at selected frequencies by manual audiometry which will be referred to as manual puretone audiometry and (2) discreet frequency or sweep frequency testing by audiomatic audiometry, referred to as automatic audiometry. This presentation defines the methods employed in manual puretone air-conduction threshold audiometry.

In a school hearing conservation program, threshold audiometry is used to define the actual hearing levels of children who have failed the identification audiometry procedures. Although a person's threshold may be defined for a variety of test signals, pure tones are used in order that the clinician may understand the child's hearing sensitivity across the frequency spectrum for each ear.

The classical tuning fork tests are the historical antecedents of manual puretone audiometry. The development of the audiometer, approximately fifty years ago, made it possible to control the intensity and duration of a puretone signal in ways that were not possible with tuning forks. Thus, the audiometer permitted more reliable and, in some cases, more sophisticated tests than had been possible with tuning forks. However, even when calibration of equipment is maintained, valid measurements of a person's hearing sensitivity are not always obtained. One critical factor in the determination of hearing thresholds is the test methodology employed. In this discussion a standard set of procedures is presented for accomplishing manual puretone audiometry in a way that will minimize differences in test results based on examiner methodology.

Factors affecting assessment of puretone thresholds

Three general factors that may influence the assessment of puretone thresholds are: (1) the instructions to the individual being tested, (2) the response task given to the individual, and (3) the manner in which the tester interprets the individual's response behavior during the test.

Instructions. Taken in order, we will consider the instructions first. They should be phrased in language appropriate to the child and should: (1) indicate he is to respond whenever the tone is heard even if barely heard; (2) indicate the method of response to be used; (3) indicate the need to signal as soon as the tone comes on and to continue to signal until the tone goes off; and (4) describe the method of indicating the ear in which the signal is heard.

In working with school-aged children, the instructions will necessarily differ in wording depending on whether the child is Kindergarten age or high-school age. However, the basic principles enumerated above should be covered in any instructions regardless of the child's age. An example of instructions for a Kindergarten child, which meet the requirements above, might be as follows: "You are going to hear a soft sound which is kind of like a whistle. No matter how soft it is, I would like you to raise your hand when you hear it and put your hand down when it goes away. Let's practice now." At this point, the examiner may either whistle audibly or turn the tone on with the hearing level dial set at maximum output while holding the earphones in front of the child. Both the examiner and child are to raise their hand when the tone comes on and put it down when it goes away. If the child is hesitant to respond, the examiner may take his hand and show him the response using adequate social reinforcement such as a smile, or saying that's a good job, etc.

Once the child has shown that he can signal properly, the instructions might continue "Gee, that's great--now I'm going to make the game harder since you're doing so well. Let's say that if you hear the whistle in this ear you will point to it and if you hear it in this ear you will point to it. Now remember, raise your hand even if it is a very soft or tiny sound."

Those instructions may be contrasted to an example of the instructions one might use with an older child, such as: "You are going to hear some very soft tones. I would like you to raise your hand as soon as you hear a tone, keep it up as long as you hear the tone, and put it down when the tone goes away. Please use your right hand for your right ear, and your left hand for your left ear. Remember, even if a tone is very soft, raise your hand when you hear it, keep it up as long as you hear it, and put it down when it goes away." In each set of instructions, the four factors listed have been included, even though the language used has been different. Remember, the important thing is that you phrase the instructions in language comfortable to your manner of speaking and appropriate to the age of the child.

Response task. The second general area considered is that of response task. Some form of overt responses are required from the subject to signal when the tone goes on and when the tone goes off. Any response task meeting this criterion is acceptable. Examples of commonly used responses include: (1) raising and lowering the finger, hand, or arm; and (2) pressing and releasing a signal-light switch. Children of school age may be expected to accomplish any of these tasks. Occasionally, a Kindergarten child or pre-school child may be fearful in a test situation and it may be advantageous to substitute a play-audiometry response task to alleviate his fears. In such a case, the placement of a ring on a spindle or the dropping

of a marble in a bottle, or similar activities may substitute as a response. However, when such a response is used, remember that the child is responding only to tone onset. Since the tester gets only one indication of response per signal, more sampling may be needed at each hearing level.

Response behavior. The final general area is that of interpretation of response behavior. The primary factors which the tester may use in determining an individual's threshold are: (1) latency of response, (2) presence of both on and off responses, and (3) the number of false alarm responses.

The latency of the on responses should be consistent. That is, the child should signal the tone onset without a long delay preceding his response. The first response to a tone in an ascending series may be slower than succeeding responses. However, the response to a tone presented 5 dB higher should be strong and without hesitation. If the subject does not respond sharply to tones that are 5 dB higher than the initial response level, the validity of the first response is suspect. In such a case, the tester should go up in additional 5 dB steps until a sharp, clear, consistent response is obtained.

Since each tone presentation provides the opportunity for two responses--on response and off response--the tester should take advantage of both in determining the validity of a child's response. The tester should remember that in determining whether or not a response is valid, the ability of the child to signal onset and offset greatly facilitates the decision. If a child is simply raising his hand any time while the tone is on and putting it back down immediately, there is a much better chance of his randomly responding and hitting some portion of the tone-on interval, when in fact he doesn't hear the tone at all. Thus, if a child is not signaling both tone on and tone off, the tester should remove the earphones and reinstruct the child.

Finally, false-alarm responses make it very difficult for the tester to determine threshold. A false-alarm response is defined as a response by the child when no tone is present. The tester should remember that the child may well think that he is pleasing the tester when he raises his hand; in fact, almost any child left for some time with no tone on will, following the instructions, raise his hand, imagining that he does hear a tone. Some children are so eager to try to please, that they present a very high rate of false-alarm responses. When this occurs, the tester should first reinstruct the child saying "Remember, I want you to raise your hand when you are sure (emphasize the sure) that you hear the tone." This instruction is different than the original instruction and suggests to the child that he is to be sure he hears it. For a child presenting a high rate of false-alarms, however, such reinstruction will

often allow the test to be completed. Along with the reinstruction the tester may want to present a tone at a clearly audible level and, demonstrate to the child again, the raising of his hand, keeping it up as long as the tone is on and putting it down when it goes away. Coupled with strong social reinforcement, such demonstration and/or reinstruction will often reduce the rate of false-alarm responses. Another procedure which can be used in many cases is that of pulse counting. The tester tells the child that he may hear either one, two, or three pulses and he is to report which. Then by pulsing the tone appropriately, the validity of the response can be determined by the accuracy of the child's response.

Threshold measurement procedures

Now let us consider the actual threshold measurement method. The basic procedure consists of two separate and distinct steps: (1) familiarization and (2) threshold sampling. These steps are the same regardless of the frequencies being tested, or the type of test--air conduction or bone conduction.

Familiarization. Familiarization assures the examiner that the subject understands and can perform the response task expected in addition to letting the subject become familiar with the particular signal. The specific step to be used is as follows: with the tone turned on, but completely attenuated (hearing level dial at zero), the intensity is gradually increased until a response occurs. Turn the tone off. This simple step has accomplished both of our desired goals. First, the subject has demonstrated his ability to complete the response task. Second, the subject is familiar with the frequency of the tone under test. This step of familiarization is preliminary to threshold determination.

Threshold sampling. The method of threshold exploration described is considered a standard procedure for manual puretone audiometry.

First, the exploration for threshold is carried out by means of short tone presentations, varying in duration. These presentations normally don't need to be longer than one to two seconds; however, they should always be of sufficient duration to allow the subject time to respond. The interval between tone presentations should be of variable length also, but should be no shorter than the test tone.

Second, the level of each presentation is determined by the response to the preceding presentation. The first tone is presented at a level 20 dB below the level of the familiarization response. After each failure to respond to a tone, the hearing level is increased 5 dB until the first response occurs. Following the first response, the tone is raised 5 dB for the next presentation. After the second consecutive response, the tone is decreased 15 dB and another series of ascending presentations is begun. It is to be emphasized that during threshold determination, the hearing level dial is never turned while the tone is on.

Third, following the above rules for level of signal, threshold is defined arbitrarily as the lowest level at which responses occur in at least half of the ascents with a minimum requirement of three responses at a single level.

Let us look at an example. Assume that we're dealing with an older child who has been properly instructed, the ear under test has been selected, and the frequency to be tested has been selected. We first set the hearing level dial at 0 dB; next we turn the tone on by depressing the tone interrupter switch; we then sweep the hearing level dial up until the child signals that he hears the tone. Assume that he does this at a hearing level of 50 dB. We then turn the tone off. Next, to start threshold exploration, we attenuate (reduce) the hearing level dial setting by 20 dB, or to a setting of 30 dB HL, and present the first signal. If the subject does not respond to that tone, we increase the level by 5 dB to 35 dB HL and again present a tone. Assuming that he does respond at this level, we go up an additional 5 dB and present a tone at 40 dB HL. When he responds with his second consecutive response, we attenuate the tone 15 dB and again ascend in 5 dB steps. Threshold would be defined as the lowest level at which he responds correctly a minimum of three times with the maximum number of ascents being 6. In summary, the specific test methodology consists of two steps, familiarization and threshold exploration. The procedures to be followed by the tester are specifically detailed.

Test frequencies

Next, we need to consider the frequencies to be tested, the order, and the recording of results. Thresholds are usually determined at octave intervals from 250 Hz through 8000 Hz. If the difference in thresholds obtained between any two successive octaves is 20 dB or more, and the audiometer allows for testing at interoctave intervals, complete such a measurement. An example would be a hearing level of 20 dB at 1000 Hz with a hearing level in the same ear of 50 dB at 2000 Hz. In such a case, a measurement at 1500 Hz is indicated. When appropriate information is available, the better ear shall be tested first. The initial test frequency shall be 1000 Hz. If no information is available as to the status of the ears, it is suggested that the test begin in the right ear at 1000 Hz and next, complete the measurement at 1000 Hz in the left ear. Continue the test in the better ear, if one is determined. The sequence is to be 1000 Hz, 500 Hz, 250 Hz, retest at 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz. Having completed the test in one ear, complete the measurement in the second ear following the same sequence.

Recording results

The results of the test are to be recorded using the following symbols: a "O" for air conduction measurements in the right ear

and an "X" for air conduction measurements in the left ear. Air conduction scores for each ear are to be interconnected by a solid line. If no response is obtained at the maximum limit of the audiometer, the symbol for that ear is to be placed on the audiogram at the level of the maximum output of the audiometer with an arrow pointing down.

To review, the method for manual air-conduction puretone threshold audiometry is as follows: Instruct the child in language appropriate for his age indicating the response task, which is to include a signaling of both tone on and tone off as well as the ear in which the tone is heard. Next, the determination of threshold includes both familiarization and threshold exploration. Familiarization is accomplished by turning on the tone and gradually sweeping up until the child signals that he hears it. Threshold exploration is then begun at a level 20 dB below the child's response to the familiarization tone. It consists of short-duration tones at levels based on the response to the preceding presentation. After each failure to respond, the level is raised 5 dB until a response is obtained and then raised an additional 5 dB. After two consecutive responses, the intensity is decreased 15 dB and another series initiated. Threshold is defined as the lowest level at which responses occur in at least half of the ascents with a minimum of three responses required at a single level. Air-conduction threshold measurements are completed at octave intervals from 250 Hz through 8000 Hz, and at interoctave intervals when any two successive octaves differ by 20 dB or more. The order of presentation begins at 1000 Hz, tests the lower frequencies, and then sequentially the frequencies above 1000 Hz.

Possible problems in air-conduction measurements

Equipment calibration. The condition and calibration of your test equipment is, of course crucial to the obtaining of valid results. Research has demonstrated that many portable audiometers in use in public school hearing conservation programs do not meet calibration standards. On the other hand, a recent study has demonstrated that if such equipment is placed in full calibration, it maintains good stability during periods of heavy use, suggesting the fact that many audiometers used in schools may never have been placed in full calibration. The tester must determine that the equipment being used is receiving the necessary full-scale calibration on at least an annual basis. In addition to this, many school districts may want to provide the necessary sound measurement equipment to complete intensity-only calibrations on a more frequent basis. Finally, each piece of equipment should be checked by the tester prior to the start of the day's testing. To complete such a check, the audiometer is to be plugged in and allowed to warm up at least 5 minutes. The

tester then puts the earphones on himself, turns the hearing level dial to 30 dB and listens to the signal first in one ear and then in the other ear. This check allows the tester to be sure that equal signals are being delivered to each earphone. Then, the tester quickly determines his threshold in each ear. The obtained results should compare favorably with his known threshold. If not, he should compare his results on that audiometer to those obtained on a spare audiometer. In addition to determining threshold, he listens for any audible clicks or other sounds which might clue the child as to the presence of the tone. If such clicks, etc., are present, again a spare audiometer should be used. A reserve complement of 15-20 percent is suggested (or one spare for every six audiometers in use).

Test environment. The test environment must be adequately quiet to allow testing to be completed. Ambient noise is present predominantly in the low frequencies and will interfere most with testing at 250 Hz, and then 500 Hz and 1000 Hz. In most school environments, testing at frequencies above 1000 Hz can be completed without undue concern for ambient noise. A check to determine the adequacy of a test environment may be completed by using a sound level meter and comparing results to normative values. If such equipment is not available, you may presume that testing cannot be satisfactorily completed at any frequency where your threshold is shifted by 5 dB or more by the presence of ambient noise. You cannot correct for ambient noise by subtracting the amount of shift in your threshold from the results obtained for each child. Ambient noise affects persons differentially depending upon whether or not they have a hearing loss. Thus, if you find that the noise level is too high for a given test frequency, you simply cannot test adequately at that frequency.

Earphone placement. The placement of earphones is important. The tester should place earphones on the child and see that they are properly aligned with the ear canals. Occasionally a child, in placing the earphones, will not provide such an alignment and may even, in rare cases, fold the pinna over the ear in pulling the phones on from behind. Also, if in testing you find a loss only at 6000 or 8000 Hz, move the earphones slightly and re-test. Such results may reflect the presence of standing waves in the ear canal which will produce spurious results. If such a movement does shift the threshold to a better level, record the better level.

Unintentional cues. The mannerisms of the tester may provide unintentional cues to the child as to when the tone is on and when it is off. For example, if you look down at the test equipment, adjust the hearing level dial setting, look up at the child, and then turn

the tone on, he may be responding only to the fact that you have looked at him expectantly. More subtle cues such as shoulder movement, etc. may be apparent to the child. Some testers have the child face away to avoid this problem. However, the tester then loses many valuable cues to responses in the form of eye movement, etc. Also, without eye contact, some social reinforcement such as a smile or a nod of the head cannot be used.

A good way to check for the possibility of unintentional cues is to have a friend serve as a subject and observe carefully your testing manner to see if any detectable cues are present. Similar to observable visual clues are timing cues which may be apparent. Testers often fall into a rhythmic pattern of tone presentation. The child may be responding to an expected tone based on the past rhythm of presentations rather than to an actual tone. Again, falling into a rhythmic pattern may produce a higher rate of false alarms. One solution is to vary the interval between tone presentations to see that you don't fall into a rhythm pattern.

Misrecording of data. Misrecording of data may include two types of errors. First is the simple error in recording data on the audiogram form. Be sure that you have entered the threshold at the proper hearing level and for the proper frequency and ear. The second type of error may be the intentional misrecording of data such as occurs because of previous expectations. For example, in bone conduction testing we often expect that the obtained score can be no poorer than the air-conduction score. If in actuality we find a score which is 10 dB poorer, the tester very often will shift that score to make it agree with the air-conduction score. In just such a manner, we may expect a child to have better hearing than he is demonstrating, and so accept any response which happens to occur during the time the tone was on, rather than holding to the rather rigorous response criteria described above. The tester's first reaction to this type of information is "Who, me?", yet I would dare say that all persons who test hearing have at one time or another misrecorded data in this manner.

Audiometer cues. Just as the tester may provide unintentional cues to the child, the operation of the audiometer may provide unwanted cues. For example, a noisy tone interrupter switch or the overzealous pushing of a tone interrupter switch may provide a clearly audible click which the child detects. The child is not intentionally trying to cheat on the hearing test; however, when he hears this click, he is apt to imagine the tone is present and so signal. Other examples of instrument cues include the reflection of a tone-on light on the face plate of the audiometer from a shiny button on the tester's clothing, the visibility of this tone light from the back of the audiometer so that the child clearly can see the tone-on light going

on and off, or the presence of acoustic clicks coupled with the signal, as discussed under calibration. Again, careful observation is necessary to find and/or avoid this problem.

Fear of test situation. Some children, particularly very young children, may be frightened by the circumstances surrounding the test. In most such cases, simple reinstruction and/or inclusion of play-audiometry response procedures will allow the tester to complete the test. In addition to the play procedures involving placement of a ring on a spindle or dropping of a marble in a bottle, one might consider such tasks as pulse counting or ear-choice methods. In pulse counting, the child is told that he will hear either one, two, or three tones and he is to tell you the number he hears. For some children, this sort of procedure will make the task more game-like and thereby more pleasurable. Also, this procedure may help in cases of children giving high rates of false-alarm responses. In the ear-choice technique, the child is simply to point to the ear in which he hears the tone and the tester randomly varies between the ears rather than testing all frequencies in one ear first. Again, the task is somewhat more game-like and thereby more attractive to some children.

To conclude, the completion of manual puretone air-conduction audiometry demands first that proper equipment, maintained and calibrated, be provided. Secondly, an adequate test environment must be available. Third, the child must be properly instructed. Fourth, a standard method of measurement including both familiarization and threshold determination is to be employed. Fifth, the obtained results are to be recorded properly on the audiogram blank, and finally, the tester must avoid any unintentional cues which would influence the test results.

TYMPANOMETRY TESTING PROCEDURE

I. Set the equipment in the "ready" position:

1. Impedance Audiometer turned "on."
2. Pressure dial set at "0."
3. Sensitivity dial set at "off."
4. Recorder level in the "load" position.
5. Both edges of the recorder paper fastened down.

II. To obtain a tympanogram:

1. Note if the air pressure needle reads "0." If it does not, call a consultant for adjustment of the manometer.
2. Examine the child's ear for excessive cerumin and to determine canal size.
3. Place a PVC eartip on the probe and insert into test ear.
4. To obtain a seal, introduce +200 mm H_2O pressure by rotating the air pressure dial clockwise. The seal is airtight if the needle holds at +200 mm H_2O or leaks by no more than 20 mm H_2O in 10 seconds.
5. If no seal can be obtained within 60 seconds, after trying several styles and sizes of tips, attempt a seal in the opposite ear. If a seal cannot be obtained on the opposite ear either, call a consultant for inspection of the equipment.
6. If no seal can be obtained within 60 seconds in either ear, schedule the child for a reexamination and proceed to the next child.
7. Turn sensitivity knob to "1."
8. Adjust the intensity knob until the compliance change meter needle is on the red zero (0).
9. Move the recorder lever from the load position to "up," then move it to "down," allowing the arm to stop in each position momentarily.
10. Reduce the air pressure smoothly to at least -200 mm H_2O by pushing the Positive-Negative switch to the left.
11. Put the recorder lever in the "load" position.
12. Push the air discharge button and remove the probe tip from the ear.
13. Repeat the procedure for the second test ear.

A NOTE ON TYMPANOMETRY

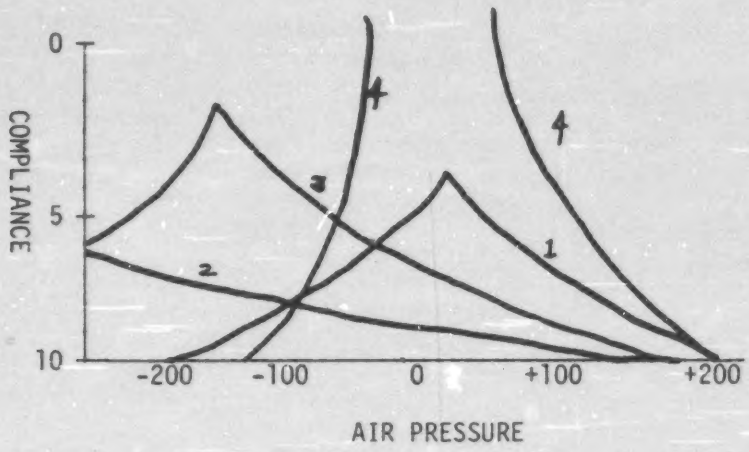
Tympanometry is one form of a group of measurements known as acoustic-impedance measurements. Acoustic-impedance measurements describe the opposition encountered by an acoustic wave. Thus, acoustic-impedance measurements may be used to chart the opposition provided by the tympanic membrane and middle ear structures to the movement of sound energy through the structures. Any change in the normal state of these structures will cause a change in the amount of opposition encountered by an acoustic wave.

Two basic parameters are involved in describing the middle ear system: compliance and impedance. Compliance is an expression of the middle ear system's ability to transmit energy through the tympanic membrane to the oval window. It is a measure of the mobility of the system. Impedance is a complex ratio which describes the total resistance of the system to the flow of energy. It is a measure of the immobility of the system.

In tympanometry, a puretone is presented through a probe tube to the tympanic membrane. The amount of sound energy reflected back from the tympanic membrane (measured in acoustic ohms) describes the relative efficiency of the system. If much of the sound energy is reflected off the tympanic membrane, rather than passed through the oval window, the impedance is said to be high, and the system stiff or less compliant than normal. This is often the case in ears presenting an otitis media, where the ossicular chain and tympanic membrane are impeded by fluid. It is also seen in cases of otosclerosis. The opposite picture is generally seen in an ossicular discontinuity, where more than normal sound pressure is passed through the oval window. Here the system is said to be hypercompliant.

In tympanometry, compliance is measured under conditions of varying air pressures in the external auditory canal. The range of pressure extends from +200 mm H_2O to -200 mm H_2O. Maximum compliance or "ambient" pressure will be obtained at the point at which the air pressure in the external canal is equal to the air pressure in the middle ear. In a normal ear, since the air pressure in the ear canal and the air pressure in the middle ear are equal or very nearly equal, maximum compliance will be obtained at 0 mm H_2O. If the point of maximum compliance is measured at -200 mm H_2O, there is said to be "negative pressure" within the middle ear, indicating that the tympanic membrane is probably retracted. Children with a serous otitis media often show both reduced compliance and negative middle ear air pressure, suggesting that not only is the eardrum retracted, but that the middle ear structures are not free to vibrate with maximum efficiency. Incipient or resolving phases of otitis media may

show only negative internal air pressure with normal compliance. A purulent otitis media may show positive internal air pressure. Thus, many different conditions of compliance as a function of applied air pressure may exist. Several considered distinctive enough for classification are illustrated below.



1. normal
2. negative pressure and reduced compliance
3. negative pressure and normal compliance
4. normal pressure and super-compliance

Tympanometry and the puretone audiogram

Substantial research evidence exists to indicate that air-conduction/bone conduction comparisons are a reasonably inefficient means of detecting all cases of active or past middle ear pathology. Identification audiometry, which involves only air-conduction measurement, is even less accurate in such detections. The significance of tympanometry in terms of school hearing conservation programs is, therefore, related to its sensitivity in detecting middle ear problems. Since hearing loss due to an otitis media typically fluctuates, some children may not be identified by puretone screening, yet will show abnormal tympanographic patterns. Whether or not there is an educational handicap accompanying the middle ear pathology, regular audiological evaluation in conjunction with a medical referral are required for proper management of the child. For children presenting the opposite testing results, passing tympanometry and failing on puretone screening and threshold measures, the hearing loss is most likely sensori-neural in nature. These children become an immediate educational concern. Thus, tympanometry in conjunction with puretone audiometry allows the definition of medically significant middle-ear problems as well as the definition of educationally significant hearing problems.

TYMPANOMETRY

Tympanometry is one form of a group of measurements known as acoustic-impedance measurements. In simple terms, acoustic-impedance measurements describe the opposition encountered by an acoustic wave. Thus, acoustic-impedance measurements may be used to chart the opposition provided by the tympanic membrane and middle ear structures to the movement of sound energy through the structures. The tympanic membrane and the ossicular chain serve the important function of providing an efficient transfer of energy from the air-conducted sound of the ear canal to the fluid-conducted energy of the inner ear. Any change in the normal state of these structures will cause a change in the amount of opposition encountered by an acoustic wave. For example, the presence of fluid in the middle ear such as occurs in otitis media, may greatly increase the opposition or acoustic-impedance of the system. Since acoustic-impedance measurements allow assessment of this opposition, they provide the clinician with a means of determining the efficiency of the middle ear structures. From these measurements, one may infer the presence or absence of certain middle-ear pathologies.

Several terms are used frequently in describing this unique measurement system. The first term is impedance. Impedance is a complex ratio which we may define as the total resistance to the flow of energy or a measure of the immobility of a system. Thus acoustic-impedance measurements chart the opposition to movement encountered by an acoustic wave. The next term is compliance. Compliance is defined as a measure of the mobility of a system, and units of compliance may

be used to express the mobility of the middle-ear structures.

The third term is tympanometry. Tympanometry is an objective measurement of the mobility or compliance of the tympanic membrane under conditions of varying air pressure. Thus, to complete tympanometry, we must make measurements of the compliance of the tympanic membrane as we introduce changes in air pressure in the external auditory canal. In review, impedance is defined as the total opposition to energy flow while compliance is a measurement of the mobility of a system. Tympanometry is the measurement of the compliance of the tympanic membrane under conditions of varying air pressure in the external auditory canal.

To assist in understanding these concepts further, consider several examples. Note first that the tympanic membrane will be maximally compliant or mobile when the air pressure in the middle ear is equal to the air pressure in the external canal. Thus, in a normal ear, since the air pressure in the ear canal and the air pressure in the middle ear are equal or very nearly equal, maximum compliance will be obtained at zero or ambient air pressure. However, consider a child with intact ear drums and poorly functioning Eustachian tubes which cause his tympanic membranes to be retracted. In such a case, the point of maximum compliance will more than likely be found when negative air pressure values are introduced in the ear canal. The negative pressure in the ear canal returns the ear drum to its normal position from the retracted position and allows the system to be maximally compliant. Thus, when maximum compliance is obtained under conditions of negative pressure, one knows that the tympanic membrane

is retracted. A second example might be the child with fluid in the middle ear. In such a case, the middle ear structures are not free to vibrate and the maximum compliance value obtained would be much lower than in cases with normal middle-ear conditions. The introduction of different air pressures into the external canal may alter only slightly the compliance readings since the structures simply are not free to move regardless of the pressure in the external canal. In both of these examples of pathology, the results of tympanometry would first indicate that the middle ear structures or conditions were abnormal and second would suggest the basis of the abnormality.

Now let's consider how acoustic-impedance measurements may be completed. Although several approaches to the measurement of acoustic-impedance are available, we shall limit our discussion to the use of the electro-acoustic impedance bridge. With this instrument, a puretone signal called the probe tone is introduced through a tube which is sealed in the ear canal. This signal strikes the tympanic membrane and most of the energy is transmitted through the middle-ear structures. However, depending upon the compliance of the tympanic membrane, certain amounts of energy are reflected back. A second tube, also sealed in the ear canal, leads to a microphone which monitors the amount of reflected energy. The bridge is designed to compare the relationship between the puretone signal being presented to the ear canal and the reflected signal coming back to the bridge. This comparison provides measurements of the compliance of the tympanic membrane in arbitrary compliance units. For purposes of tympanometry, a third tube is sealed in the ear canal and allows for the provision

of both positive air pressures and negative air pressures to be introduced into the ear canal. Thus, the compliance of the tympanic membrane can be measured under varying conditions of air pressure in the external canal which, as you will recall, was our definition of tympanometry. To recapitulate, three tubes, obviously very small, are sealed in the ear canal. One transmits a probe tone, a second allows for a monitoring of the reflected sound energy from the tympanic membrane and the third allows for application of variable air pressure in the canal. We must emphasize that the purpose of the probe tone is solely to provide an acoustic wave so that we may make acoustic-impedance measurements of the system. The individual does not respond to the tone and it is unimportant whether he hears the tone or not, since we are making a measurement of the impedance of the middle ear structures, and not a measurement of the hearing sensitivity of the total system. Since acoustic-impedance measurements do not require any specific response by the individual, they may be completed on anyone who is cooperative to the point of remaining still for the short time necessary to complete the measurement. Thus, they can be completed on neonates, mentally retarded children, and other difficult-to-test patients. Also, such measurements can be completed under sedation.

The significance of tympanometry in terms of a school hearing conservation program is related to its sensitivity in detecting middle ear problems. Substantial research evidence exists that air-conduction--bone-conduction comparisons are a reasonably inefficient means of detecting all cases of active or past middle-ear pathology.

Identification audiometry, which involves only air-conduction measurement, is even less accurate in such detections. Thus, tympanometry can become part of an identification audiometry battery which will allow for the definition of medically significant middle-ear problems as well as the definition of educationally significant hearing losses.

APPENDIX III

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DO NOT USE PEN. ERASE COMPLETELY ANY CHANGES YOU MAKE.

DISTRICT	SCH	EXAM DATE MO	DY	YR

LAST NAME	FIRST NAME	MI

STUDENT NUMBER

DATE OF BIRTH MO	DY	YR

GRADE LEVEL: PK, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

ETHNIC GROUP
- NATIVE AMER.
- BLACK
- MEX. AMER.
- ORIENTAL
- PUERTO RICAN
- WHITE
- OTHER, ...

HL? YES / NO / UNK

SEX M / F

TAMI HEARING RECORD DATA FORM 74-1
Capitol Region Education Council
Windsor, Connecticut
(203) 522-6137

PURETONE SCREENING

10

INITIAL / RECHECK

TESTER	AUD. NO.

LEFT EAR

	5	1	2	4		INCL	CNT
PASS	P	P	P	P	P		
FAIL	F	F	F	F	F		

RIGHT EAR

	.5	1	2	4		INCL	CNT
PASS	P	P	P	P	P		
FAIL	F	F	F	F	F		

TYMPANOMETRY SCREENING

11

INITIAL / RECHECK

TESTER	AUD. NO.

	LEFT PEAK	RIGHT PEAK
RESULT		
PASS		
FAIL		
INCL		
CNT		

PURETONE THRESHOLD

12

INITIAL / RECHECK

TESTER	AUD. NO.

PURETONE AVERAGE .5, 1, 2 KHz

AVG.	EAR L	R
0-20		
21-40		
41-55		
56-70		
71-90		
91+		
RESULT	L	R
PASS		
FAIL		
INCL		
CNT		

DC 32-420 OPTICAL SCANNING FORMS by OPTICAL SCANNING CORPORATION

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PROCEDURES FOR COMPLETING TAMI FORM 74-1

Use only a dull, number 2 pencil. Erase any error completely; smudges will be misinterpreted by the computer.

Complete the heading blocks first.

Blacken the designated area to the printed bracket, being certain to cover the number (or letter) completely. If necessary, go over the number (letter) several times to insure a fully blackened area.

Stay in the correct columns.

A. Section 1

1. Heading: complete the heading to the following sub-sections:

    a. District number
    b. School code

2. Sense-mark areas: fill in sense-mark areas for the above sub-sections.

3. Exam date will be completed by volunteers on the date of examination.

B. Section 2

1. Heading: enter as many letters of the child's last and first names as space allows. Enter the middle initial.

2. Sense-mark areas: starting in the first column for the last name, blacken the appropriate box beneath the letter of the name. Be careful to stay in the correct column and to blacken the areas completely.

C. Section 3

1. Heading: student numbers have been provided by the TAMI Project. If unnumbered forms are used, student numbers will be provided at the time of examination.

2. Sense-mark areas: where TAMI numbers are provided, blacken sense-mark numerals. The right-most digit in the number (i.e. the digit in the "units" position) must be entered in the right-most column.

D. Section 4

1. Heading: enter child's birthdate using numerals. Example: if the child's birthdate is June 9, 1964, enter 060964.

2. Sense-mark area: blacken appropriate numbers.

E. Section 5

Blacken the child's equivalent grade level. Be certain to fill in the area completely for grade.

F. Section 6

Blacken the box corresponding to the child's most representative ethnic group. Native American is the same as American Indian.

G. Section 7

Mark YES if the child is known to have a hearing loss;
Mark NO if he does not have a hearing loss;
Mark UNK if the child's hearing status is unknown.

H. Section 8

Blacken the box corresponding to the child's sex.

I. Section 9

1. Two left most columns: enter the number of absences which the student has accumulated since school began in September.

2. Middle two columns: enter the child's equivalent grade level for READING. Use two digits. Example: For a child reading on the 4th grade level, enter "04." Record "90" for children reading below the first-grade level.

3. Two right-most columns: enter the child's equivalent level for ARITHMETIC. Use two digits. Example: for the child functioning at 5th grade level in arithmetic, record "05." Record "90" for children functioning below the first-grade level.

Many thanks for your help! You are making it possible to test far more children in a limited time than would otherwise be possible.

PROJECT TAMI QUESTIONNAIRE

ADMINISTRATIVE STAFF

We realize that it is the end of the school year with subsequent pressures on your time. However, we would appreciate your careful thought to the following questions and your prompt return of this form. If possible, we would appreciate your either returning the forms to the Speech and Hearing Supervisor of your town or sending it directly to the TAMI staff at their office by June 30. The address is:

Project TAMI
Capitol Region Education Council
443 Windsor Avenue
Windsor, Connecticut 06095

Please feel free to add comments as you desire. It was very enjoyable working with each of you. You have all been exceptionally cooperative and your continuing interest will go a long way towards making the future of the TAMI model a success. Thank you all for working so hard.

Respondent's position_____ District/Town_____

1. How interested are you in continuing to have tympanometry incorporated in the hearing screening program in your school(s)?

   _____ Greatly interested
   _____ Generally interested
   _____ Not particularly interested
   _____ Disinterested

2. How feasible is it to complete mass hearing-screening testing in your school within two-four days?

   _____ Completely feasible
   _____ Generally feasible
   _____ Not particularly feasible
   _____ Infeasible

3. Given the requirement for a "silent" room (difficult, we realize, in a public school), what is the likelihood that such a room for puretone testing (such as that utilized for TAMI) could be used for up to three days.

   _____ Such space can be guaranteed
   _____ Possibly found
   _____ Not likely to be found
   _____ Unavailable

4. How strongly would you encourage your town/board of education to invest in a tympanometer within the next three years?

_____ Strongly encourage

_____ Generally encourage

_____ Discourage

_____ Strongly discourage

5. In your opinion, should the detection of abnormal middle ear conditions (as provided by Tympanometry) be incorporated routinely in the health services provided by your schools?

_____ Definitely "yes"

_____ Generally "yes"

_____ Probably not

_____ Definitely not

6. How often are the audiometers in your district sent out for service and recalibration?

_____ Every six months

_____ Yearly

_____ Every other year

_____ Every third year

_____ Less often

7. Given the size of the Project and the time limits under which it had to be administered, how efficient was the execution of the TAMI Project in your school(s)?

_____ Exceptionally efficient

_____ Generally efficient

_____ Somewhat inefficient

_____ Inefficient

8. Given the same constraints as in #7, above, how much disruption was there of your school's daily routine?

_____ Complete disruption

_____ Generally disruption

_____ Some limited disruption

_____ No disruption at all

9. Comments received from teachers about TAMI have been generally:

_____ Strongly positive
_____ Generally positive
_____ Somewhat negative
_____ Strongly negative

10. Comments you have received from nurses and speech and hearing clinicians have been:

_____ Strongly positive
_____ Generally positive
_____ Somewhat negative
_____ Strongly negative

11. Comments from parents of the children tested have been:

_____ Strongly positive
_____ Generally positive
_____ Somewhat negative
_____ Strongly negative

12. Did your school(s) have adequate advance notice (including news coverage) of the project?

_____ Definitely "yes"
_____ Generally "yes"
_____ Generally no
_____ Definitely no

Again, thank you all for working so hard. We hope that we have a chance to meet again soon. Have a nice summer.

Sincerely,

THE TAMI STAFF

TAMI FOLLOW-UP QUESTIONNAIRE

(Nursing and Clinical Staff)

Respondent's Job Classification_____
District/Town_____

I. INTRODUCTORY INFORMATION

A. Meetings

(1) Did the supervisory meetings meet your specific needs for:

	YES	NO
(a) Information for your staff?	_____	_____
(b) Information for administration?	_____	_____
(c) Information for parents?	_____	_____
(d) Information for volunteers?	_____	_____

(2) What other specific information could have been included?

_____

B. Handouts/Mailed Information

(1) Did you receive the pink TAMI data sheets well enough in advance? Yes_____ No_____
If not, how much lead time would you prefer?_____

(2) Did you receive adequate instructions for:

	YES	NO
(a) Filling out forms?	_____	_____
(b) Organizing volunteers?	_____	_____
(c) Obtaining adequate test sites?	_____	_____

(3) Have you found the various fact sheets useful?

	YES	NO
(a) Note on Tympanometry	_____	_____
(b) Note on puretone screening	_____	_____
(c) Referral form	_____	_____

(4) Suggestions and Comments_____

_____

II. TRAINING SESSIONS

A. Puretone

(1) Was there adequate theoretical discussion?

	YES	NO
(a) puretone screening	_____	_____
(b) puretone threshold	_____	_____

(2) Was more written/handout information felt necessary?

YES____ NO____

(3) Were our instructions on procedures clear enough?

YES____ NO____ If no, please comment_____

_____

(4) Was enough time spent on the theory and procedures for obtaining puretone results? YES____ NO____

(5) Do you feel that you gained new skills in:

	YES	NO
(a) puretone screening	_____	_____
(b) threshold procedures	_____	_____

If no, please comment_____

_____

(6) What in the puretone presentation would you suggest for retention or change in future preliminary workshops to an identification program?_____

_____

_____

B. Tympanometry

(1) Was there adequate theoretical diccussion?

YES____ NO____

(2) Was more written/handout information felt necessary?

YES____ NO____

(3) Given the time limitations, do you feel that you gained sufficient knowledge of how to run the tympanometer?

YES____ NO____

(4) What in the tympanometry presentation would you suggest for retention or change in future preliminary workshops to an identification audiometry program?_____

_____

_____

III. FEEDBACK TO PROJECT

A. Personnel (Nurses and Clinicians)

(1) Puretone

(a) Are the nurses and clinicians willing to use the ASHA model, i.e. screening at 1, 2 and 4 K Hz?

YES____ NO____

If no, why?_____

(b) Do you feel you gained new skills in:
screening procedures YES____ NO____
threshold procedures YES____ NO____

(c) Do you feel a need for more or less supervision on:
screening procedures MORE____ LESS____
threshold procedures MORE____ LESS____

(d) Was supervision adequate at the time of testing?
YES____ NO____
If no, please comment_____

(2) Tympanometry

(a) Do you feel you gained the skills to use tympanometry in the future? YES____ NO____

(b) In what areas do you feel weak?

(1) obtaining a seal _____
(2) working the instrument _____
(3) troubleshooting equipment breakdowns _____
(4) calibrating the equipment _____
(5) setting up and taking down the equipment _____
(6) interpreting pass/fail _____
(7) interpreting tympanographs _____
(8) recording data _____
(9) other _____

(c) Do you feel you have a basic understanding of what tympanometry measures? YES____ NO____

(d) Was supervision adequate at the time of testing?
YES____ NO____
If no, please comment_____

B. Administrators

(1) Puretone

(a) Considering the effectiveness of the project in identifying children with hearing losses, do you think you can effect any changes in the conditions under which you must do puretone testing in the future?
YES____ NO____
If no, please comment_____
_____

(b) Is it possible for your school system to complete puretone testing within 2-3 days per school?
YES____ NO____

(2) Tympanometry

(a) Would the administration support the use of tympanometry in the future? YES____ NO____

(b) Do you expect that your town will invest in tympanometric equipment in the future? YES____ NO____

(c) What financial aid for purchasing and maintaining audiological equipment do you have? (i.e., Lions, Rotary, school board, PTA, etc...)

_____

(d) If tympanometers were available through CREC, in what month and for how long would you want to use them?

_____

C. Teachers

(1) Were your teachers generally cooperative:

(a) in getting ready for TAMI? YES____ NO____

(b) during testing? YES____ NO____

(2) What was the nature of their response?

Positive_____ Negative_____

Please comment_____

D. Parents

(1) Have the parents of your town supported the use of tympanometry? General comments_____

(2) Do you know what percentage of parents followed through on the Project's recommendations?_____

(3) What was the general feeling of the parents involved as volunteers?

_____

(4) Would you employ volunteers in a future project?

_____

IV. REFERRAL COMMENTS

A. Referral

(1) How much time elapsed between the completion of testing and when you received the student listing?_____

(2) How much time has elapsed between the return of the TAMI data and referral?_____

(3) Are you referring the borderline cases? (i.e. "2NN3" in one ear and normal puretone results). YES____ NO____

(4) Do you generally refer to an otologist or local pediatrician?
Often_____ Seldom_____ Never_____

B. Medical Response to tympanometry referrals

(1) Has your school discussed tympanometry with your doctors? What were their comments?_____

(2) What do you feel is the best way to approach your doctors with information about tympanometry?_____
_____

C. Follow-Up Procedures

(1) Do you arrange to retest each child placed under medical care? YES____ NO____

(2) Who (nurse or clinician) consults with the classroom teacher when a specific child is referred? _____

V. FUTURE CONSIDERATIONS FOR AN IDENTIFICATION PROGRAM

(1) Do you plan to use the TAMI model in the schools for:

Next year?	YES____	NO____
In the future?	YES____	NO____

(2) Do you feel a program like TAMI has in any way changed the working relationship between the nursing and speech and hearing staff? YES____ NO____

If so, how? _____

(3) Would you consider doing a similar team approach in the future? YES____ NO____

(4) Do you see a need for ongoing consultation and/or training in:

Puretone screening	YES____	NO____
Puretone threshold	YES____	NO____
Tympanometry	YES____	NO____

(5) Would you be interested in an Impedance workshop next fall? YES____ NO____

Areas of interest_____
_____
_____

(6) Did any nurses or speech and hearing staff outside of those involved in TAMI express an interest in future workshops and identification programs of this sort?

YES____ NO____

(7) Under what format would you like to use tympanometry in the future?

Kindergarten only_____
K and first grade_____
K through third_____
K and rescreen only_____
Other_____

Thank you for your assistance and cooperation in attaining this additional information.

Have a nice summer.

Sincerely,

The TAMI staff

SAMPLE HEARING SCREENING REFERRAL FORM

School_____

District_____

Name_____

Date of Screening_____

Dear Dr._____

The above-named child participated in our hearing screening program. We refer him to you for medical examination. Test results were as follows:

(1) Puretone Screening

Right Ear		Left Ear
_____	Pass	_____
_____	Fail	_____

(2) Puretone Threshold

Right Ear		Left Ear
_____	Within normal range (0-20 db HTL)	_____
_____	Mild loss (20-40 db HTL)	_____
_____	Moderate loss (41-55 db HTL)	_____
_____	Severe loss (56-70 db HTL)	_____

(3) Tympanometry

Right Ear Left Ear

_____Normal middle ear pressure; normal middle ear compliance_____

_____Negative middle ear pressure; normal middle ear compliance_____

_____Normal middle ear pressure; reduced middle ear compliance_____

_____Negative middle ear pressure; reduced middle ear compliance____

MANAGEMENT SERVICES RECORD

Name of Child_____
TAMI ID #_____
Date of Report_____
Date Identified_____
School_____
City_____

Professional respondent(s) completing this form:_____

(Complete all applicable items in each section)

I. Results of TAMI Hearing Screening

___Passed puretone threshold ___Failed puretone threshold
___Passed tympanometry ___Failed tympanometry

II. TAMI Referral Statement Recommended

___Educational management
___Medical management
___Both
___Notify parents

III. Status of Referral

Notification of Findings Made to

___Physician
___School nurse
___Lang., Speech and Hear. Clinician
___School principal
___Classroom Teacher
___Parents
___Other (Specify)_____

Medical Management and Intervention

___Physician's management ___in process ___completed ___continuing
___Otologist's management ___in process ___completed ___continuing

Recommended Medical Intervention

Record Procedures Used (i.e., wax removal, surgery, etc.)

_____
_____
_____

Date_____M.D._____

Medical Findings

___Confirm results of hearing testing
___Do not confirm results of hearing testing

Recommended Medical Follow-Up

___Recheck by managing M.D. Date_____
___Surgery by managing M.D. Date_____
___Referral to_____ Date_____
___Other_____ Date_____

Educational Management and Intervention

___Lang., Speech and Hear. Clinician ___in process ___completed ___continuing
___Audiologist ___in process ___completed ___continuing
___Classroom teacher ___in process ___completed ___continuing

Recommended Educational Intervention
___Preferential seating
___Hearing aid
___Language and speech services
___PPT conference
___Classroom teacher conference
___Parent conference
___Tutorial help
___Special class placement (title and location_____)
___No further management
___Other (specify_____)

Recommended Educational Follow-up
___Preferential seating
___Hearing aid assessment
___PPT referral
___Classroom teacher conference
___Parent conference
___Hearing rechecks ___bi-monthly ___monthly ___quarterly ___annually

Audiological Management and Intervention
___Audiologist ___in process ___completed ___continuing
___Nurse ___in process ___completed ___continuing
___Lang., Speech and Hear. Clinician ___in process ___completed ___continuing

___Rescreen Date_____
Results

	Audiological	Tympanometric
Pass:	RE___ LE___	RE___ LE___
Fail:	RE___ LE___	RE___ LE___

Complete Evaluation Date_____
Results

Type of loss: ___Sensori-neural ___Conductive
Degree of loss: RE LE

Comments:_____ _____ normal _____
_____ _____ moderate _____
_____ _____ severe _____

Recommended Audiological Follow-up

___Hearing aid management
___Referral to_____Date_____
___Hearing recheck

	Audiological	Tympanometric
___bi-monthly	_____	_____
___monthly	_____	_____
___quarterly	_____	_____
___annually	_____	_____

___Other (Specify _____)

Audiological Findings
___Confirm results of TAMI hearing screening
___Do not confirm results of TAMI hearing screening

AUDIOMETER CALIBRATION WORKSHEET

DATE_____

IDENTIFICATION INFORMATION:

EXAMINER NAME_____

#_____

Owner_____

Model_____

Year_____

Serial No._____

TAMI #_____

Physical Characteristics (Mechanical Condition)

Dials (Loose, malaligned, clicks?) _____

Knobs (Loose, noisy?) _____

Earphone Cushions (Split, deteriorated?)_____

Cords (Split, frayed?) _____

Noise During Test (Extraneous noise)

Attenuator Hum (dirty?) _____

Radiation from Chassis (oscillating? components)_____

Power supply hum _____

Clicks when changing Int. or Freq. _____

Other_____

_____

GROSS AUDITORY TEST

_____ Cords - Set at 1000 Hz, 70 dB, HTL, tone on. Jiggle earphone cords back and forth one half turn. If tone is intermittent, either the cord is loose or defective. First try to tighten screws. If there is no change, replace cord.

_____ Power Hums - Set audiometer at 40 dB HL and increase intensity; listen for any random signals.

_____ Rise Time - Move dials (attenuator and frequency) and interrupter switch. Judge if there are any audible clicks above threshold levels.

_____ Linearity - Set at 2000 Hz and increase intensity in 5 dB steps. Give gross estimate of uniformity.

AUDIOMETER CALIBRATION WORKSHEET

TAMI FORM 74-

DISTRICT _____

TAMI # _____ MAKE _____ EXAMINER NAME _____

SERIAL # _____ MODEL _____ EXAMINER # _____ DATE _____

			INTENSITY CALIBRATION				FREQUENCY (Hz) CALIBRATION			PURITY OF TONES (dB)						RISE/DECAY TIME CAL. (msec)			
			LEFT PHONE		RIGHT PHONE					LEFT PHONE			RIGHT PHONE			LEFT PHONE		RIGHT PHONE	
FREQUENCY (Hz)	REF. SPL* MIC* #439403 (TDH 39)	TOLERANCE (±dB)	**SPL	ERROR dB	**SPL	ERROR dB	MEASURED FREQUENCY	TOLERANCE (±Hz)	ERROR	FREQ. OF LGST. HARM.	SPL OF LGST. HARM.		FREQ. OF LGST. HARM.	SPL OF LGST. HARM.		RISE TIME 20-100	DECAY TIME 5-100	RISE TIME 20-100	DECAY TIME 5-100
125	114.5	5						4				COMMENTS:			COMMENTS:				
250	95.0	3						8											
500	81.0	3						15											
750	78.0	3						23											
1000	77.0	3						30											
1500	76.5	3						45											
2000	79.0	3						60											
3000	81.0	3						90											
4000	80.5	4						120											
6000	86.5	5						180											
8000	80.5	5						240											

*Includes corrections for using B&K microphone Type 4144 (SN439403) with protecting cover.

**Measured with 70 dB input.

TAMI FORM 74-

ATTENUATOR LINEARITY

TEST FREQ. _____ Hz DATE _____

PHONE _____

DIAL SETTING Hz	MEASURED LEVEL SPL	LINEARITY VALUE
110		
105		
100		
95		
90		
85		
80		
75		
70		
65		
60		
55		
50		
45		
40		
35		
30		
25		
20		
15		
10		
5		
0		

(3.5-6.5 dB TOTAL RANGE)

OVERALL LINEARITY

MAX. SPL _____

MIN. SPL _____ _____ dB

(±5 dB TOLERANCE)

ENVIRONMENTAL NOISE RECORD

TAMI FORM 74-

DISTRICT _____ SCHOOL _____ DATE _____

SLM # _____

OPERATOR NAME	PISTON PHONE LEVEL	ROOM	LOCATION WITHIN ROOM	TIME	TEST TYPE (1) PTS (2) TPS (3) PTT	LINEAR	dBC	dBA	500 Hz OCTAVE BAND	COMMENTS

TESTING FACILITIES AND SCHEDULES

District_____ Principal_____
School_____ Nurse_____
Initial Test Date_____ Speech Clinician_____
Rescreen Test Date_____

Testing Rooms: Names and/or numbers _____

_____

Schedules

Num. Chn. in:	Num. Classes for:	Room Nos.:	Times Available:
KAM_____	_____	_____	_____
KPM_____	_____	_____	_____
1st_____	_____	_____	_____
2nd_____	_____	_____	_____
3rd_____	_____	_____	_____
5th_____	_____	_____	_____
Other_____	_____	_____	_____

Arrival/Dismissal times:	Recess times:	Lunch times:
KAM_____	_____	_____
KPM_____	_____	_____
1st_____	_____	_____
2nd_____	_____	_____
3rd_____	_____	_____
5th_____	_____	_____
Other_____	_____	_____

Other times not available for testing:_____

TAMI FORM 74-

PRINCIPAL _____

NURSE _____

CLINCIAN _____

ORDER OF TESTING

DATE _____

SCHOOL _____

DISTRICT _____

TEST SCHEDULE	GRADE	TEACHER & ROOM NO.	TOTAL CLASS ENROLLMENT	NO. CHILDREN TO BE TESTED	No. CHILDREN ABSENT	NO. CHILDREN W/O PARENTAL CONSENT	NO. CHILDREN TO BE RETESTED
9:00							
9:15							
9:30							
9:45							
10:00							
10:15							
10:30							
10:45							
11:00							
LUNCH							
12:45							
1:00							
1:15							
1:30							
1:45							
2:00							
2:15							

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